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ABSTRACT

A study was conducted in order to investigate the factor structure of the Graduate Record Examinations (GRE) Aptitude Test, which now includes an analytical module. Comparison of the factor structures of the Aptitude Test before and after modification suggested that the factor structure of the verbal and quantitative sections of the test has been relatively unaffected by changes made in order to introduce the analytical module. The restructured test does, however, have a distinct, identifiable analytical dimension that is strongly related to the verbal and quantitative dimensions underlying performance on the test. Separate analyses of the analytical section of two forms revealed dimensions in the analytical items, particularly in the "analysis of explanations" item type, that may have practical value for test development activities. A look at another analytical item type, "evaluation of evidence," being considered for inclusion in future forms of the Aptitude Test, suggested that the ability to answer these items depends more on general reading comprehension ability than on analytical ability as it is now measured in the restructured test. Extension of factor solutions to various background variables, such as major field of study, yielded additional evidence supporting the discriminant validity of the verbal, quantitative, and analytical factors found in the test. (Author)

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A FACTOR ANALYTIC STUDY OF THE RESTRUCTURED GRE APTITUDE TEST

Spencer S. Swinton

and

Donald E. Powers

GRE Board Professional Report GREB No. 77-6P

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EDUCATIONAL TESTING SERVICE, PRINCETON, NJ

A Factor Analytic Study of the Restructured GRE Aptitude Test

Spencer S. Swinton

and

Donald E. Powers

GRE 77-6P

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Contents

	Page
Abstract	1
Executive Summary	2
Introduction	4
Previous Research	4
Purpose	5
Procedures and Rationale	6
Results	10
Analysis of Analytical Items	10
Analysis of Verbal, Quantitative, and Analytical Items	21
Analysis of Parcels	33
Relationship of Evaluation of Evidence Items to the Restructured Test	58
Extension of Item-parcel Factors into Background Variables	61
Extension of Varimax Factors	77
Discussion and Summary	83
Structure of the New Test	83
Difficulty and Speededness	83
Complexity of Analytical Items	84
Relationships to Background Variables	85
Issues Raised	85
References	87
Appendix	91
Examples of Analytical Item Types	91

List of Tables

Page

Table 1. Summary of Orthogonal Dimensions Found in the Analytical Sections of Two Operational Forms of the GRE Aptitude Test. 11

Table 2. Summary of Dimensions Found in Odd and Even Numbered Item-level Analyses after Orthogonal (Varimax) Rotations 12

Table 3. Summary of Factors Found in Parcel-level Analyses after Orthogonal (Varimax) and Oblique (Oblimin and Geoplane) Rotation 13

Table 4. Varimax Factor Loadings for Analytical Items in Form A. 15

Table 5. Varimax Factor Loadings for Analytical Items in Form B. 18

Table 6. Varimax Factor Loadings for Verbal, Quantitative, and Analytical Items (Form A -- Odd Items). 22

Table 7. Varimax Factor Loadings for Verbal, Quantitative, and Analytical Items (Form A -- Even Items) 27

Table 8. Item-parcel Designations and Their Means and Standard Deviations. 35

Table 9. Varimax Factor Loadings for Item-parcel Analysis. . . . 37

Table 10. Oblimin Factor Pattern for Item-parcel Analysis (Partial Correlations). 41

Table 11. Oblimin Factor Structure for Item-parcel Analysis (Zero-Order Correlations) 43

Table 12. Oblimin Factor Correlations 45

Table 13. Geoplane Factor Pattern for Item-parcel Analysis (Partial Correlations). 48

Table 14. Geoplane Factor Correlations. 51

Table 15. Geoplane Factor Structure for Item-parcel Analysis (Zero-Order Correlations) 52

Page

Table 16. Principal Components of Geoplane Factors. 57

Table 17. Factor Extension Loadings of Analytical Parcels and Evaluation of Evidence Parcels on Operational Form Varimax Factors 60

Table 18. Correlations of Extension Variables (Parcels) with Geoplane Factors (Zero-Order Correlations). 62

Table 19. Loadings of Extension Variables (Parcels) on Geoplane Factors (Partial Correlations). 63

Table 20. Groups of Disciplines Used as Major Fields. 65

Table 21. Geoplane Extension Mean Standard Differences. 66

Table 22. Ranks of Mean Scores on Selected Geoplane Factors for Major Areas 69

Table 23. Ranks of Mean Scores on Geoplane Factors for Graduate Major Field Subgroups 71

Table 24. Geoplane Extension Primary Loadings (Partial Correlations) 76

Table 25. Varimax Extension Loadings. 79

Table 26. Ranks of Mean Scores on Selected Varimax Factors for Major Areas 81

Table 27. Ranks of Mean Scores on Varimax Factors for Major Field Subgroups 81

List of Figures

Page

Figure 1. Hypothesized Analytic and Reading Item Structure and Oblimin Factors. 46

Figure 2. Structure Correlations and Pattern Loadings for Correlated Factors 55

Figure 3. Relationship of Geoplane and Varimax Reading and Analytical Factors 56

Figure 4. Circumplex Structure: Principal Components of Geoplane Factors 59

Figure 5. Ranks of Mean Scores on Selected Geoplane Factors for Major Graduate Groups. 70

Figure 6. Ranks of Mean Scores on Selected Geoplane Factors for Social Science Graduate Subgroups. 70

Figure 7. Ranks of Mean Scores on Selected Geoplane Factors for Humanities Graduate Subgroups. 70

Figure 8. Ranks of Mean Scores on Selected Geoplane Factors for Biological Science Subgroups 73

Figure 9. Ranks of Mean Scores on Selected Geoplane Factors for Physical Science Subgroups 73

Figure 10. Equal Structural Correlations and Unequal Pattern Loadings with Correlated Factors 74

Abstract

A study was conducted in order to investigate the factor structure of the GRE Aptitude Test, which now includes an analytical module. Comparison of the factor structures of the Aptitude Test before and after modification suggested that the factor structure of the verbal and quantitative sections of the test has been relatively unaffected by changes made in order to introduce the analytical module. The restructured test does, however, have a distinct, identifiable analytical dimension that is strongly related to the verbal and quantitative dimensions underlying performance on the test.

Separate analyses of the analytical section of two forms revealed dimensions in the analytical items, particularly in the analysis of explanations item type, that may have practical value for test development activities.

A further look at another analytical item type, evaluation of evidence, being considered for inclusion in future forms of the Aptitude Test, suggested that the ability to answer these items depends more on general reading comprehension ability than on analytical ability as it is now measured in the restructured test.

Extension of factor solutions to various background variables, such as major field of study, yielded additional evidence supporting the discriminant validity of the verbal, quantitative, and analytical factors found in the test.

Executive Summary

The major purpose of the study was to develop a factor analytic description of the new, restructed GRE Aptitude Test, which now includes an analytical section. Results of this study were anticipated to have relevance for helping to define the construct validity of the new test and to provide additional information about the analytical item types included in the new section. Primary analyses were based on a random sample of approximately 4,000 examinees who took one form of the Aptitude Test. Both item-level and subset or parcel-based solutions were obtained using principal axis (minres) factoring. Factors were subsequently rotated according to both orthogonal and oblique criteria.

The factor structure of the verbal and quantitative sections of the restructured test has been little affected by the changes made in order to introduce the analytical module, i.e., introducing shorter reading passages and quantitative comparison items. The major verbal and quantitative factors in the restructured test were defined, as they were in the test prior to restructuring, by (a) reading comprehension items, including easy sentence completion items, (b) discrete verbal items (vocabulary), especially the more difficult antonym and analogy items, and (c) quantitative items. The verbal and quantitative factors in the test before and after restructuring are similar, accounting for comparable portions of the test's common variance.

The addition of the new analytical items to the GRE Aptitude Test has introduced a new analytical dimension to the test. This dimension is defined primarily by one complex analytical item type, analysis of explanations (especially those having certain keyed choices), and to a lesser extent, by logical diagram items. The major oblique factors in the restructured test were found to be reading comprehension, vocabulary, quantitative ability, and analytical reasoning. The latter factor was highly correlated with reading comprehension.

Analyses suggested that the analysis of explanations item type is quite complex. The multidimensionality of this item type was seen from distinct dimensions associated with keyed item choices. The analysis of explanations item type consists of a passage stating a fact, or a series of facts, and a result. Following the result are several statements for which the examinee is to decide, in a sequential fashion, whether each statement is (a) inconsistent with, (b) a possible adequate explanation of, (c) deducible from, (d) relevant to, or (e) irrelevant to the fact situation and the result. Choices are the same for all items. Choice C items and especially choice B and choice D items were relatively better indicators of analytical ability than were choice A and E items, which were generally easier and more closely associated with reading comprehension ability. With respect to another item type, analytical reasoning, there was some suggestion in the data that the distinction between ordered (e.g., distances and calendar dates) and unordered relationships may be an important distinction.

The oblique factors--reading comprehension, vocabulary, quantitative ability, and analytic ability--were extended to background variables: sex, ethnicity, undergraduate grade average, extracurricular achievements, and twelve groupings of intended graduate major fields. Since, except for grade average, these categories were binary, the extension loadings were essentially point-biserials, and it was appropriate to interpret only relative magnitudes or ranks, rather than absolute magnitudes of correlations.

Although all factors correlated positively with undergraduate grades, patterns among intended major fields were strikingly different. Humanities and basic social science majors showed a characteristic dip in their quantitative ranks. Science, engineering, health, and applied biological science majors were relatively higher on quantitative than on other abilities. Basic biological science majors and applied social science (primarily education) majors showed relatively even profiles. The analytic factor did not particularly distinguish across the arts/science continuum, but instead it distinguished within each general category. Within the social sciences, basic social science was extremely high on analytic ability; social science professions (including business and social work), low; and applied social science, lowest. Within the humanities, philosophy, religion, and art history were high; health (largely nursing), lower; and applied fields (agriculture, forestry, home economics), lowest. Within the physical sciences, the rank order was mathematics/physics, chemistry/earth science, and engineering.

It would thus seem that analytic ability distinguishes more theoretical majors from more applied majors within general fields. The highest ranking groups on the factor: basic social sciences, basic biological sciences, mathematics/physics, and nonlanguage humanities, each represent the theoretically oriented pole of their general field. Relationships to extracurricular achievements support this interpretation.

Introduction

One portion of the recent effort aimed at restructuring the GRE Aptitude Test (Altman et al., 1975) was directed at the possible introduction of a new analytical reasoning module to supplement the verbal and quantitative sections of the Aptitude Test, and thus to provide broadened measurement. Investigations of seven experimental analytical item types (Conrad, 1976) resulted in the selection of three of these item types (analytical reasoning, logical diagrams, and analysis of explanations) for the analytical section of the restructured Aptitude Test, which was introduced operationally in October, 1977. Additional research on the analytical item types (Powers et al., 1978) showed that six of them seemed to measure dimensions not shared with either the verbal or quantitative sections of the test. Another item type, evaluation of evidence, still under consideration for inclusion in the analytical section of the test, was investigated further as part of this study.

Embedded in the report of findings concerning the development of the new module was a call for "research and program activities (to) support its further validation, continued improvement, and proper use" (Conrad, 1976). The present study was proposed in response to that call, particularly as it related to articulating the validity of the new test. The present study used factor analytic methodology, an approach that has been considered by many to be useful in establishing the construct validity of measurement instruments (Cronbach, 1971).

The major purpose of this study was to develop a factor analytic description of the new, restructured Aptitude Test, which would become part of a growing body of knowledge resulting from a variety of research studies sponsored by the GRE Board. The development of a network of relationships among test scores and other variables eventually enables us to assess the degree to which the scores measure important and distinct traits. To the extent that this is established, we say we have evidence of "construct validity." Evidence of construct validity is generally thought to result not from a single study, but from a variety of related research (American Psychological Association, 1974) based on correlational, experimental, or logical evidence (Cronbach, 1971). The present study focuses on correlational evidence.

Previous Research

Previous research has produced two factor analytic studies relevant to this effort. The first (Powers, Swinton, & Carlson, 1977) provided a factor analytic description of the Aptitude Test as it was before restructuring. The second study provided additional information about the seven abstract reasoning item types already investigated for possible inclusion in the new analytical section of the test (Powers et al., 1978). This latter investigation demonstrated through factor extension methodology that,

although each of the seven analytical item types could be partially described in terms of the common factors that underlie the verbal and quantitative sections of the test, there were unique dimensions associated with each of the experimental analytical item types. Since no examinee took more than one experimental test, a straightforward investigation of the relationship(s) among the new item types was not possible. It was therefore not possible to conclude from the Powers et al. (1978) study whether the unique dimensions found in each experimental analytical test were different ones, or whether each was a manifestation of a more global analytical ability common to all.

Purpose

The study reported here addresses the relationships among the shortened verbal and quantitative sections and the new analytical section of the restructured test. On the basis of the previous research, it was anticipated that it might be possible either to identify a global analytical factor analogous to previously documented verbal and quantitative factors or to determine the unique contribution of each item type to the GRE Aptitude Test.

Secondary purposes of the study were the following:

- to provide additional information about new analytical items that might be useful in guiding the development of additional parallel forms,
- to report information about the number, type, and relative weights of factors underlying reported scores,
- to compare the structure of the former test and the newer one, and
- to provide information regarding the desirability of a possible future change in the composition of the analytical measure (i.e., substitution or addition of evaluation of evidence items).

Since the evaluation of evidence item type is under consideration as a component of future analytical sections of the test, this item type was spiralled-in to the pretest section of one of the operational forms of the restructured test for the October 1977 administration. A factor extension analysis of this evaluation of evidence test permitted another look at this item type in terms not only of the Aptitude Test's verbal and quantitative factors, but also its analytical dimension(s).

Procedures and Rationale

In outline, the procedures used in this study entailed the following steps:

1. Selecting the appropriate level for data analysis. Both item-level analyses and analyses based on subsets of items were used. Item-level analyses were computed for all odd items in the total test and again for all even items in one form. Item-level analyses based on only analytical items were also conducted and repeated with the use of an alternate form of the test.

Subsets or parcels of items were also developed for one form of the test. All items from the verbal, quantitative, and analytical sections were used in devising item parcels.

2. Tetrachoric correlation coefficients were used in all item-level analyses and product-moment correlations in item-parcel analyses.

3. Principal axis factoring was used to determine the approximate number of factors to be retained. Both the magnitude of and the break in magnitude in eigenvalues and the proportion of common variance explained was used to decide the appropriate number of factors to be designated for subsequent minres solutions.

4. Communality estimates in all analyses resulted from a minres procedure, which started initially with communality estimates based on a method suggested by Ledyard Tucker. These initial estimates were used to expedite convergence.

5. Several minres solutions, based on the suggested appropriate numbers of factors, were computed for each of the five data matrices considered.

6. Several rotational schemes (varimax, oblimin, and geoplane) were tried with each minres solution. Varimax rotation was used for the item-level analysis of analytic items alone. Both varimax and oblimin rotations were tried for the odd and even item-level analyses of all items. Varimax, oblimin, and geoplane criteria were used in the subset or parcel-based solutions.

7. The solutions reported were chosen on the basis of interpretability. With the exception of the oblimin solution for the item-level analyses, all solutions have been reported. However, preferred solutions have been designated and reasons for preferences have been given.

8. Item-parcel solutions, based on both varimax and geoplane rotations, were extended (Dwyer, 1937; Harman, 1938) to the evaluation of evidence items in the pretest section of the test to obtain the loadings of these items on the operational factors. These solutions were also extended to certain background variables to facilitate the interpretation of factors.

A more detailed discussion and rationale for the procedures listed above is given below.

In this effort, as in any factor analytic study, it was possible to employ a variety of methods, characterized by, among other things, the method of analysis (in terms of the type of correlation matrix analyzed and the type of communality estimate employed) and the method of rotation. In addition, the analysis of a multisection test such as the GRE Aptitude Test required a decision regarding whether to analyze all sections simultaneously or each separately. This latter decision was dictated by, among other considerations, how fine-grained an analysis was desired. A related issue required a decision with respect to the number of variables to be included: whether to consider each item as a variable or to form homogeneous subsets of items, a strategy that requires a procedure to cluster items in some meaningful way.

The two previous factor analytic studies provided guidance concerning the most appropriate procedures for the present project. The following strategies were used to analyze data from the first (October 1977) administration of the restructured Aptitude Test.

Random samples of approximately 3,900 and 5,800 individuals taking one of two forms given for that administration were used. Analyses were based upon the simultaneous consideration of all sections--verbal, quantitative, and analytical--since the primary concern was with relationships among item types irrespective of their placement in a particular section. The only exception was a separate additional analysis of the new analytical section, since we desired to learn more about the dimensions underlying this new module.

The use of homogeneous, mutually exclusive subsets of items was chosen over an analysis based on individual items, although certain issues related to factoring individual items are also involved in subset-based analyses, where they may be as complex. The two previous factor analytic studies provided the bases upon which subsets of items could be confidently specified. Subsets were defined primarily by nominal item type: analogies, opposites, sentence completions, reading comprehension, general quantitative, practical application word problems, data interpretation, logical diagrams, analysis of explanations, analytical reasoning, and, through factor extension analysis, evaluation of evidence (included in the pretest section). Item difficulty and speededness were also used to define more homogeneous subsets of items. Item types having the same set of response choices for all items were also grouped according to the response option keyed as correct.

Item subsets were quite small (4 items) and numerous in order to permit as many variables as possible to enter into the definition of factors. To this end, the categories mentioned above were crossed to achieve a fairly substantial number of variables.

In general, the use of item parcels was chosen in order to circumvent some of the problems often encountered in using inter-item correlations, which were used in a previous study. The rationale employed in forming subsets of items was based on that which underlies Cattell and Burdsal's (1975) solution to the item vs. subset controversy. These authors cite two fundamental approaches to forming item parcels--grouping items by apparent content and grouping them according to their intercorrelations--rejecting the first as being too subjective and the latter as being somewhat destructive of inherent simple structure. Their recommendation is for two factor analyses--one on the items and one on the parcelled item variables that result from the item-level factoring. That principle has been applied here to obtain item dimensions for forming subsets. Subsets have been identified by reference to previous work or by additional analyses using inter-item correlations. The latter provided further corroboration of test dimensions, particularly those underlying the analytical portion of the test. Tetrachoric coefficients were used in these item-level analyses.

Communality estimates were obtained from the use of minres factoring (Harman and Jones, 1966), a method that obtains communality estimates consistent with the goal of reproducing the off-diagonal elements of the correlation matrix. Initial communality estimates for the minres solution were obtained by a method suggested by Tucker (see Carlson, 1967) in order to expedite convergence.

Several rotational schemes were used. The first was a cluster-oriented approach within which both orthogonal and oblique solutions were obtained. According to either the varimax criterion (Kaiser, 1958) or the oblimin (quartimin) criterion (Jennrich and Sampson, 1966). In addition to these cluster-oriented approaches, geoplane, a hyperplane location approach that yields an oblique solution (Yates, Note 1; 1978), was employed. These two different approaches were intended to complement each other. Although the objective of cluster-oriented schemes is usually to associate each variable with a single factor, under the geoplane criterion factors are defined by virtue of the set of variables to which they are unrelated, while the variables themselves are permitted to be factorially complex. Greater freedom exists in the choice of factor axes when planes or hyperplanes, rather than reference axes, are chosen to represent clusters of variables (Harman, 1976, p. 96). The geoplane criterion "encourages" variables to be of less than full factorial complexity, but does not "force" any of them to be unifactorial, as the cluster-oriented solutions are prone to do. Also, with geoplane, the preference is to obtain a small number of factors thought to represent the more basic psychological functions or abilities in line with Thurstone's original concept of simple structure. In contrast, the use of the cluster-oriented rotational criteria has generally led to retaining a larger number of dimensions. These dimensions may not necessarily represent hypothetical determinants in the true factor analytic sense, but they do represent manifest components of test score variance that may have important implications for test development and assembly.

Because the minres procedure requires an estimate of the number of factors to be extracted, principal axis factor analysis was performed as a first step in all analyses. Decisions regarding the number of factors to be retained for the final minres solution were based on the break in, and the magnitude of, eigenvalues, and on the proportion of common variance accounted for by various numbers of factors. Generally, several minres solutions were computed for each analysis and subjected to alternative rotational schemes, with the most stable and interpretable solution being reported.

Variables derived from the background information questions contained in the GRE registration instructions were included in the analyses as extension variables. These variables included sex, ethnic status, English language ability, undergraduate major area, intended graduate degree objective and major, and undergraduate grades. Correlation of factors with this information was anticipated to be useful in developing a greater understanding of the nature of those verbal, quantitative, and analytical traits underlying performance on the GRE Aptitude Test.

The evaluation of evidence pretest items were also included as extension variables, extending the structure of the operational test to these items in order to determine their relationship to factors found in the operational portion of the test.

Results

Overview of factors in the several analyses. This report gives the findings of factor analyses of five distinct matrices, with up to three different rotations applied to the resulting factors. For convenience of discussion, factors are referred to by Roman numerals within each analysis and rotation. Factors with the same number in different analyses have no necessary relationship to one another. To aid the reader in following the discussion, Tables 1, 2, and 3 summarize the factors described in the various sections of the report.

Table 1 gives the six factors resulting from item-level tetrachoric factor analyses of the analytical sections of two forms of the GRE Aptitude Test. These results are discussed in the following section.

Table 2 summarizes the eight factors resulting from item-level tetrachoric factor analyses of the even items and of the odd items of the entire test. These factors in varimax and oblimin rotations form the bases for the formation of item clusters in the following analyses. The oblimin solutions, except for slight differences in the order of factors, were essentially the same as the varimax solutions and have not been reported to avoid redundancy.

Table 3 summarizes the factors resulting from the factor analyses of product-moment correlations of 53 item clusters derived from the entire test. The varimax and geoplane factors yield descriptions of the structure of the test and form the bases for the factor extension analyses, which conclude the report. The oblimin rotation, which is discussed briefly, was not found to yield a reasonable simple structure.

The factors summarized in Tables 1 and 2 may be thought of not only as intermediate steps in the development of item clusters, but also as useful ways of examining the fine structure of the items. The varimax and geoplane factors of Table 3 represent our final description of the structure of the test, and the dimensions that were examined to obtain evidence relating to construct validity.

Analysis of Analytical Items

Because the analytical section of the test is new, and since there seemed to be relatively more to learn about the analytical items than about the verbal and quantitative items, the analytical items were factor analyzed at the item level for each of two forms. This analysis served as the basis for forming meaningful item parcels for subsequent analyses with parcels of verbal and quantitative items. A second purpose of this analysis was to learn more about dimensions of these items that might be relevant to test specifications or item classification schemes.

Table 1

Summary of Orthogonal Dimensions Found in the Analytical Sections of Two Operational Forms of the GRE Aptitude Test

Order	Form A	Form B
I	Logical Diagrams	Logical Diagrams
II	Analysis of Explanations (Choice B)	Analysis of Explanations (Choice B)
III	Analysis of Explanations (Choice D)	Analysis of Explanations (Choice D)
IV	Analysis of Explanations (Choice C)	Speed
V	Speed	Analysis of Explanations (Choice C)
VI	Analytical Reasoning	Analytical Reasoning

Note. See Tables 4 and 5 for the detailed analyses of these factors.

Table 2

Summary of Dimensions Found in Odd and Even Numbered Item-level Analyses after Orthogonal (Varimax) Rotations

Order	Orthogonal Odd	Even
I	Reading Comprehension	Reading Comprehension
II	Vocabulary	Vocabulary
III	Difficult Quantitative	Difficult Quantitative
IV	Easy Quantitative	Easy Quantitative
V	Analysis of Explanations (Choice D)	Analysis of Explanations (Choice B)
VI	Data Interpretation	Analysis of Explanations (Choice C)
VII	Reading Comprehension (Scientific/ Technical)	Reading Comprehension (Scientific/ Technical)
VIII	Analytical Reasoning Items	Data Interpretation

Note. See Tables 6 and 7 for detailed analyses of these factors.

Table 3

Summary of Factors Found in Parcel-level Analyses after Orthogonal (Varimax) and Oblique (Oblimin and Geoplane) Rotation

Order	Varimax	Oblimin	Geoplane
I	Reading Comprehension (General Verbal Reasoning)	Easy Items	Reading Comprehension
II	General Quantitative	General Quantitative	General Quantitative
III	Vocabulary	Vocabulary	Vocabulary
IV	Reading Comprehension (Scientific/ Technical)	Reading Comprehension (Scientific/ Technical)	Analytic
V	Data Interpretation	Data Interpretation	Data Intepretation and Technical Comprehension
VI	Analytic	Analytic	Easy Quantitative

Note. See Tables 9-14 for the detailed analyses of these factors.

Six principal axis factors accounting for nearly 90% of the common variance (about 35% of the total variance) in each analytical section were retained for each and rotated according to the varimax criterion. Six factors were retained although there was a very sharp break in the magnitude of eigenvalues after the first root for each form. All six factors were clearly interpretable.

Tables 4 and 5 show the varimax factor loadings for items on each form. The solutions are quite similar, each having the same factors in very nearly the same order. The first factor to emerge from each form was one defined by high loadings for logical diagram items. Each of the 15 logical diagram items in each form had its highest loading on this factor, but only four of all the other remaining analytical items in both forms loaded highest on this factor. Three other factors for each form were associated with analysis of explanations items. Each of these factors was defined by items having particular keyed choices, with the B-choice (possible adequate explanation) factor being the most prominent in each form, the D-choice (relevant to) next most prominent, and the C-choice (deducible from) somewhat less prominent. For example, 17 of the 18 items keyed as choice B in both forms had higher loadings on Factor II than on any other. Each of the 20 D-choice items in both forms loaded highest on the factor defined by those items. No specific factors were noted for items keyed as A (inconsistent with) or E (irrelevant to). The reader is referred to the Appendix for examples of this complex item type and its answer choices.

A component of variance associated with the final items in each of the two separately timed sections of the test was noted for each form, suggesting that test performance depends somewhat on the examinees' ability to work rapidly.

A final analytical factor in each form was associated with analytical reasoning items, the third prominent item type. This analytical reasoning factor was best defined in one form by one set of items dealing with spatial relationships. In the other form, however, this factor was defined primarily by loadings from a set of analytical reasoning items having rules without strictly logical connections. The common thread of these two sets of items seems to be that they require the examinee to think in terms of an ordered sequence of some kind, in one case in terms of distances and in the other in terms of time. The other subtypes of analytical reasoning items had modest loading on this factor, but because of their position as the last items in the test, these items loaded more heavily on the speed factor than on any other.

Each form contained four items closely resembling a subtype of an item type, logical reasoning, that had previously been considered as a type to be included in the analytical section, but rejected because of a high correlation with verbal skills. None of these items exhibited high loadings on any of the six dimensions extracted from the analytical section of the test.

Table 4

Varimax Factor Loadings for Analytical Items in Form A

Keyed Choice*	Item Type	Factor I	II	III	IV	V	VI	Computed Communality
A		31	44		23			42
B		20	45					26
B			37	22				23
A	Analysis				28			12
C	of				40			19
D	Explanations	22		51				40
E		25	25					17
C		29	21		38			32
D				36				18
D		21		32				19
D		24	29	62				56
A		20	29		27			25
E								07
D	Analysis	20	31	56				50
B	of		69	36	22	21		76
C	Explanations		26		70			64
C			20		61	24		51
D				42				22
B			63	29	22	28		64
D		23	26	63				56
C					58	22		44
A		22	32		23			22
E		23	45					31
B			61	34				52
C	Analysis				62			42
B	of	22	52	28				45
A	Explanations	29	32		23			26
C					78			70
E		26	41		22			32
E		30	41					32
B			64	30				53

Factors: I Logical Diagrams II Analysis of Explanations (B) III Analysis of Explanations (D) IV Analysis of Explanations (C) V Speed VI Analytical Reasoning

*The order of these analysis explanation items have been scrambled so that the keyed answers do not correspond to the original test form.

Note. Loadings less than .20, as well as all decimal points, have been ommitted.

(Cont'd.)

Table 4

Varimax Factor Loadings for Analytical Items in Form A

(Cont'd.)

Keyed Choice*	Item Type	Factor I	II	III	IV	V	VI	Computed Communality
E			30			51		37
A			34		21	67		65
E	Analysis		23			41		28
B	of		39	31		44		49
B	Explanations		40	23		37		36
C				23	48	41		49
D			23	51		41		51
D				40		24		25
D				48		29		37
		52	37					50
		53	34	23	21			52
		66		33	25			65
		39	27					30
		52	22	29	20			48
		41		21				27
	Logical	35		22				22
	Diagrams	44	37		20			44
		71	26	34	23			75
		48		21				36
		53	21	24	24			45
		56	24	28	24			52
		44		22				32
		53	24	34	22			52
		36		23				25
	Analytical	55				30	35	54
	Reasoning	53				24	32	45
		35						21
	Logical	22	26		20			19
	Reasoning	26	20	21				20
		23	21				82	85
	Analytical	16					77	70
	Reasoning		20				72	67
						22	68	63

(Cont'd.)

Table 4

Varimax Factor Loadings for Analytical Items in Form A

(Cont'd.)

Item Choice*	Item Type	Factor I	II	III	IV	V	VI	Computed Communality
	Logical Reasoning	20	20	23	22	48		36
		26		30		38		38
				28		61	21	55
	Analytical Reasoning	23		31		60	22	57
				25		41		32
		23		36	22	33	21	38
	Common Variance	6.51	5.81	4.98	4.44	4.08	3.18	

Table 5

Varimax Factor Loadings for Analytical Items in Form B

Keyed Choice*	Item Type	Factor I	II	III	IV	V	VI	Computed Communality
C		22				58		43
B		30	45	26		20		42
A						27		10
E	Analysis	23	30	20		22		25
B	of	28	51	24				42
E	Explanations	21	28					16
A		28	23			36		30
C		21				46		28
D				32				18
C		20				53		38
E			35					18
A			25			35		24
C			25		20	38		31
D	Analysis			73				59
E	of		28	21				19
D	Explanations			74				61
B		22	66	41	21			72
B			64	31	24			62
D				63				48
E			21	47				31
E			42					27
A		26	32			57		52
B		28	47	22		27		44
A	Analysis	20	36			41		37
E	of		24					12
D	Explanations	27		36		20		29
C						63		46
B			43					21
D		21		37				22
A			24			34		21

Factors: I Logical Diagrams II Analysis of Explanations (B) III Analysis of Explanations (D) IV Speed V Analysis of Explanations (C) VI Analytical Reasoning

*The order of these analysis explanation items have been scrambled so that the keyed answers do not correspond to the original test form.

Note. Loadings less than .20, as well as all decimal points, have been omitted.

(Cont'd.)

Table 5

Varimax Factor Loadings for Analytical Items in Form B

(Cont'd.)

Keyed Choice*	Item Type	Factor I	II	III	IV	V	VI	Computed Communality
E			46	25	49	21		60
B			52	32	39			55
B			53	36	37			58
E	Analysis		32		36	22		29
C	of		25		37	49		49
[illegible]	Explanations			50	32			45
D			23	52	33			48
[illegible]			21		43	38		42
D				58	41	24		62
D				51	41	21		52
		39	28					29
		63						49
		52	[illegible]			22		41
		54						36
		61						48
	Logical	58	21	22		22		52
	Diagrams	68	24			20		64
		48						32
		70						65
		61	22			20		55
		60		20			20	52
		48						35
		51						39
		53						38
		42						24
	Analytical	25	31			21	71	75
	Reasoning	25	32				69	69
		23	25				71	67
	Logical		36					20
	Reasoning	23	29			20		24
					31		27	23
	Analytical	33			40		38	45
	Reasoning	30			36		40	43
		36		21	41		31	44

(Cont'd.)

Table 5

Varimax Factor Loadings for Analytical Items in Form B

(Cont'd.)

	Factor						Computed
	I	II	III	IV	V	VI	Communality
Logical Reasoning		22		24			21
	26		22	28			26
	23	21		61			52
Analytical Reasoning		20		68			55
				59			42
	28			64			54
Common Variance	6.93	5.25	4.99	4.54	4.15	2.56	

Probably the most interesting finding that emerges from this item-level analysis is the apparent multidimensionality of the analysis of explanations item type, dimensions being determined by keyed choice. This analysis seems to reinforce the test development staff's perceptions of the item type as covering a broad range of sophisticated analytical skills. Our data suggest that the nature of the item (i.e., the particular skills tapped) depends to a large extent on how the items are keyed. Moreover, the advisability of the test development staff's careful balancing of forms with respect to the number of keyed choices of each kind was confirmed as an important tactic for assembling analysis of explanations items.

Analysis of Verbal, Quantitative, and Analytical Items

Following preliminary analyses using Tucker estimates in a principal axis factoring of the tetrachoric correlations among even items and those among odd items, minres factoring followed by varimax rotation yielded two highly comparable eight-factor solutions (Tables 6 and 7). Odd and even items were analyzed separately in order to provide information on the instability of factors resulting from item sampling. This technique also made analysis less cumbersome by reducing the number of items (of the 205 possible) in any particular analysis. In both cases the first four factors, accounting for approximately 70% of the common variance, were as follows: I, Reading Comprehension, including easy sentence completion items and exhibiting moderate loadings on analytic items; II, Vocabulary, with highest loadings on the more difficult antonyms and analogies, and high loadings on difficult sentence completions; III, Difficult Quantitative items; and IV, Easier Quantitative Comparison items, with moderate loadings on other easy quantitative items.

The next factors extracted summarized covariance related to specific answer choices in the Analysis of Explanations item type. Factor V in the matrix of odd items showed highest loadings on analysis of explanations items with choice D. By chance, seven such items happened to occupy odd-numbered positions, whereas only three even items were keyed "D" in the even-numbered matrix. Thus, an identical factor could not arise from the even item matrix. However, two similar factors associated with analysis of explanations choices B and C did appear in the even-numbered matrix, confirming the complexity of the structure of this item type.

The remaining two factors among the even items were Factor VII, accounting for the cluster of items depending on a technical passage, and a minor Factor VIII, with highest loadings on the final set of data interpretation items.

Among the odd items, the final three factors also included Factor VII, defined by the technical passage, and Factor VI, with high loadings on data interpretation. This last factor showed small positive (.20 to

Table 6

Varimax Factor Loadings for Verbal, Quantitative, and Analytical Items (Form A -- Odd Items)

Item Number*	Keyed Choice	Item Type	Factor I	II	III	IV	V	VI	VII	VIII	Computed Communality
1			42								24
3		Sentence	49	26							33
5		Completion	58			21					45
7			26	22							17
9			55			20					41
11		Analogies	39	31	21	21					39
13			33	28							20
15			42								26
17			41	47	22						45
19			49	27							40
21		Opposites	59					20			47
23			51	36							45
25			26	27	20						22
27			32	43							33
29		Reading Passage 1	52								36

Factors: I Reading Comprehension II Vocabulary III Difficult Quantitative IV Easy Quantitative V Analysis of explanations, Choice D VI Data Interpretation VII Technical Passage Comprehension VIII Analytical Reasoning

*The order of these analysis explanation items have been scrambled so that the keyed answers do not correspond to the original test form.

Note. Loadings less than .20, as well as all decimal points, have been ommitted.

(Cont'd.)

Table 6

Varimax Factor Loadings for Verbal, Quantitative, and Analytical Items (Form A -- Odd Items)

(Cont'd.)

Item Number*	Keyed Choice	Item Type	Factor I	II	III	IV	V	VI	VII	VIII	Computed Communality
31		Reading	50			26	29				47
33		Passage 2	35		26	22					33
35			36								20
37		Reading	54	24						22	45
39		Passage 3	47	20						22	33
41			52						20	24	44
43		Reading Passage 4	43	22					23		39
45			35					21	61		62
47		Reading	29					29	75		80
49		Passage 5	24	22					77		77
51			32	27	20				79		90
53			23	33							21
55		Sentence	29	52							41
57		Completion	30	51							40
59			29	44							36
61			22	44							28
63			27	55				21			51
65		Analogies	21	62							46
67			26	71							62
69				51							34

(Cont'd.)

Table 6

Varimax Factor Loadings for Verbal, Quantitative, and Analytical Items (Form A -- Odd Items)

(Cont'd.)

Item Number*	Keyed Choice	Item Type	Factor I	II	III	IV	V	VI	VII	VIII	Computed Communality
71				58				20			45
73		Opposites		73							57
75				76							65
77				64							48
79				59							42
1			20			58					45
3			25		20	51					41
5						23					10
7			23			48					33
9			22			46					31
11					23						
13		Quantitative			32	48					40
15		Comparison			49	20					33
17					45						24
19					28						09
21			20		31	26	23				29
23					66	25	23				59
25					58	32					50
27					37					20	28
29											09
31		Regular				56					44
33		Math (RM)				47					30
35					44						22
37		Data	39		22	35					40
39		Interpretation	27		20			22			21

(Cont'd.)

Table 6

Varimax Factor Loadings for Verbal, Quantitative, and Analytical Items (Form A -- Odd Items)

(Cont'd.)

Item Number*	Keyed Choice	Item Type	Factor I	II	III	IV	V	VI	VII	VIII	Computed Communality
41		RM			29						20
43					60	39					60
45		Data				21		63			53
47		Interpretation	25					80			79
49								57			41
51					33			42			32
53		RM			51						35
55					35			29			26
	B	Analysis	35				21				20
	A	of									11
	D	Explanations		23	24		44				38
	C	(AX)	30		20	26				23	30
	D						27				17
	A		34				21				25
	D		29	22	24		50				48
	C	AX	36			25	20			29	36
	D						37				20
	D		25	24	29		51				50
	E		36				33				27
	C		22			20				25	22
	A	AX	38			24					26
	E		41				30				30
	B		31			22	39				33

(Cont'd.)

Table 6

Varimax Factor Loadings for Verbal, Quantitative, and Analytical Items (Form A -- Odd Items)

(Cont'd.)

Item Number*	Keyed Choice	Item Type	Factor I	II	III	IV	V	VI	VII	VIII	Computed Communality
	E		24				26	33			26
	E						30	24			22
	B	AX					38	29			29
	D		20	26			48	24			45
	D			21	20		45	21			38
42			47			32	32				48
44			39	24			21				32
46		Logical	20				28				23
48		Diagrams	53				33			24	50
50			26			32	28			22	34
52			30		26	33	39			24	48
54			34			26	40			26	49
56			31		22			24		28	33
58					32					20	22
60		Analytical	33	22							25
62		Reasoning	30					22		32	31
64			27					27		33	35
66			34	26			24	22		22	39
68						21	23	38		30	43
70					36			24		38	42
		Common Variance	9.22	7.29	4.69	4.34	4.26	3.29	2.90	1.93	

Table 7

Varimax Factor Loadings for Verbal, Quantitative, and Analytical Items (Form A -- Even Items)

Item Number*	Keyed Choice	Item Type	Factor I	II	III	IV	V	VI	VII	VIII	Computed Communality
2		Sentence	47	33							38
4		Completion	32	28							25
6			54	24		25					47
8			29								
10		Analogies	35								25
12			64				22			23	59
14			32	28							21
16				67							52
18		Opposites	62	29							54
20			33	65							54
22			36	43							37
24				47							27
26				34							
28		Reading	47	25							35
30		Passage 1	74			26			20		72

Factors: I Reading Comprehension II Vocabulary III Difficult Quantitative IV Easy Quantitative V Analysis of explanations (B) VI Analysis of Explanations (C) VII Technical Reading Comprehension VIII Data Interpretation

*The order of these analysis of explanation items have been scrambled so that keyed answers do not correspond to the original test form.

Note. Loadings less than .20, as well as all decimals, have been omitted.

(Cont'd.)

Table 7

Varimax Factor Loadings for Verbal, Quantitative, and Analytical Items (Form A -- Even Items)

(Cont'd.)

Item Number*	Keyed Choice	Item Type	Factor I	II	III	IV	V	VI	VII	VIII	Computed Communality
32		Reading Passage 2			38	21					27
34		Reading	38	28							26
36		Passage 3	46						20		29
38			46	28					24		40
40			38	22					21		26
42		Reading	37	34	22				21		41
44		Passage 4	28	23					23		21
46		Reading	25	21					77		74
48		Passage 5	23						63		51
50			29	20					74		75
52			24	24					53		44
54		Sentence	38	36		21				22	43
56		Completions	37	38							34
58			31	31		23				21	37
60			28	56							47

(Cont'd.)

Table 7

Varimax Factor Loadings for Verbal, Quantitative, and Analytical Items (Form A -- Even Items)

(Cont'd.)

Item Number*	Keyed Choice	Item Type	Factor I	II	III	IV	V	VI	VII	VIII	Computed Communality
62		Analogies	20	44							28
64				51							30
66			26	62							53
68				64							42
70			22	51	21						40
72		Opposites	21	67							56
74				74							60
76				61							40
78				67							53
80				62							43
2		Quantitative			20	62					44
4		Comparisons			22	66					54
6						31					
8					22	65					50
10			22		37	59					59
12				26	57						47
14			25		34	57					56
16						27					
18					24	42					27
20					52	35					43
22					37						
24					48						
26					52	23					29
28					40						36
30											21

(Cont'd.)

Table 7

Varimax Factor Loadings for Verbal, Quantitative, and Analytical Items (Form A -- Even Items)

(Cont'd.)

Item Number*	Keyed Choice	Item Type	Factor I	II	III	IV	V	VI	VII	VIII	Computed Communality
32		Regular	41		28	28					38
34		Math (RM)			40	52					50
36		Data	26		26						22
38		Interpretation	25		44	33					43
40		RM	20		40	25					32
42					57	31					45
44					23	20					
46		Data	23		38	20				30	40
48		Interpretation	21		45	23				28	43
50					47					47	51
52		RM		21	77						67
54					71						59
	A	Analysis	42		32	30					43
	B	of	24			37					25
	C	Explanations					33				
	E	(AX)	26								
	D										
	D	AX	27	24	30	22	38				43
	E										
	B		37			25	68				78
	C		25					59			48
	B		26			22	60	24			64
	C		21					61			47

(Cont'd.)

Table 7

Varimax Factor Loadings for Verbal, Quantitative, and Analytical Items (Form A -- Even Items)

(Cont'd.)

Item Number*	Keyed Choice	Item Type	Factor I	II	III	IV	V	VI	VII	VIII	Computed Communality
	A	AX	36			20					23
	B		26			57					47
	B		33			50					46
	C		28				52				42
	E		37			20	20				26
	A	AX	26				24	35	25	29	48
	B			21	24	20	39	21	21	20	46
	C				22			58	20		53
	D			20	22						
41		Logical	44			45	25				52
43		Diagrams	34		33	31	28	32		21	56
45			37		28	37	22	21			46
47			26		28						24
49			40		32	35	31	30		20	63
51			36		30	30	20	23			42
53			33	29	26			20			35
55			22		20	24					24
57		Analytical	32		34	23					30
59		Reasoning	40								23
61			37			29		23	21		36
63			29			29		22	25		33
65			29			20		25	22		35
67					20	24		29	30	24	39
69					24			25	21		23
		Common Variance	8.41	7.92	6.23	5.99	3.32	3.24	3.18	1.35	

.30) loadings at the end of the separately timed quantitative and analytical sections, and thus seemed to be influenced slightly by an element of speed that was less apparent in its counterpart even-item Factor VIII. The final factor (VIII) among the odd items was a minor factor distinguishing analytical reasoning and the final logical diagram items from the others. Because of the position of these items at the end of the test, it is as reasonable to interpret this factor as analytical speed as to conclude that these items possess some special characteristics different from other analytic items.

Oblique (oblimin) rotation of even and of odd items yielded factor patterns with sharper contrasts between high and low loadings on the correlated factors, but with few substantive differences in their interpretation. Relations of loadings to difficulty were somewhat stronger. Among the oblimin factors, intercorrelations ranged from .001 to .452. Of the factors emerging from the intercorrelations of odd items, Factor II, vocabulary, displayed a correlation greater than .40 with Factor VII, technical passages; and Factor IV, analysis of explanations (choice D), showed correlations greater than .40 with Factor VII and Factor VIII, analytical reasoning. The factors emerging from the even items showed slightly higher intercorrelations. The easy and difficult quantitative factors correlated .44. Factor VI, analysis of explanations (choice B) showed correlations greater than .40 with Factor I (reading comprehension), Factor III (easy quantitative), Factor V (analysis of explanations--choice C), and Factor VII (technical comprehension). Factor VII also correlated greater than .40 with Factor II (vocabulary), and with Factor V. The oblimin item-level results supported relationships among items found in the varimax analysis, but suggested that clusters based on the item-level results might be most clearly described by correlated factors.

Rotating the even item factors to the odd item structure as a target revealed that of the two analytic answer choice components of the even item correlations, Factor V, the B-choice analysis of explanations factor, most closely matched the odd item Factor V, D-choice items, while even item Factor VI, C-choice items, contributed the most variance toward matching odd item Factor VIII, the analytic speed factor.

The coefficients of congruence obtained from this rotation were generally above .85. Only the difficult quantitative Factor II (C = .82) and the analytic speed Factor VIII (C = .80) had lower values, indicating less successful matching of the factors from one half of the test to the other. The three verbal factors, I, II, and VII, all yielded coefficients of congruence above .92, indicating high consistency of these dimensions.

Thus, the item-level factor analysis resulted in the replication of reading comprehension, vocabulary, technical reading, quantitative ability, and data interpretation factors found in previous analyses of the GRE

(Powers, Swinton, & Carlson, 1977). Speed factors were not as prominent in these data as had been the case in the previous study, but difficulty factors were distinctly in evidence.

The addition to the restructured GRE of the analytic section introduced new sources of variance related to certain answer choices within the analysis of explanations item type, although other choices, e.g., "contradictory," or "irrelevant," seemed to be related more to the general reading comprehension factor than to any dimension unique to analytic items. Logical diagrams items, although loading on the analytic factors and the general reading comprehension factor, also showed moderate loadings on the quantitative factors. Finally, in one analysis there emerged a minor factor that may have represented a unique property of analytical reasoning items, but was probably more related to speed.

It is commonly held that spurious difficulty factors may arise in item-level factor analysis (but see MacDonald & Ahlawat, 1974). Nonlinearity can lead to the emergence of factors consisting of easy items and other factors consisting of difficult items, even though the underlying continuum is unidimensional. For this reason the item-level factors described here were treated as provisional, and were used as the basis for developing clusters of items for correlations to be input to a "parcel" factor analysis. This procedure, because parcel subscores are more reliable, should be less susceptible to the emergence of spurious difficulty factors caused by instability than are tetrachoric coefficients.[3]

Analysis of Parcels

In specifying the item parcels for this second-level analysis, certain decisions had to be made. When the same items differ on several attributes simultaneously, clustering on the basis of one attribute alone effectively forecloses the possibility that the others can emerge as factors.

However, unless some combining across possible dimensions is undertaken, parcels will consist of only one item each. The prior item-level analyses allowed us to make explicit choices in assigning items to parcels so as not to mask certain sources of variance as well as to be aware of which dimensions were being precluded from appearing by the nature of the clustering process itself.

Since the evidence for speed factors was weak in the item-level results, we chose to ignore item position as a basis for most parcels (except reading passages, data interpretation, and analysis of explanations, which are subject to passage- or diagram-dependency) and to concentrate instead on difficulty and response choice. This was not an attempt to build in difficulty factors as much as it was an effort to allow them to become manifest if they were indeed of real importance.

The interesting response choice factors that emerged in the analyses of the items of the two halves of the test led us to classify analysis of explanations items by response choice as well as by passage, and suggestions from previous analyses led to the decision to classify quantitative comparison items by response D, "insufficient" information vs. other responses, with other responses clustered by difficulty. Discrete verbal items and sentence completions were clustered by difficulty within item type, and passages 3 and 5, with eight items each, were divided into four-item parcels based on difficulty. Data interpretation items were put into three parcels, and regular mathematics items were clustered by type (algebra, geometry, and word problems). Logical diagrams yielded four clusters based on difficulty. Analytical reasoning items yielded three, each based on a common stimulus. The four logical reasoning items comprised a single parcel. Although certain dimensions of possible interest were sacrificed in this procedure, all dimensions except speededness, which had emerged in the item-level analyses, were afforded the opportunity to appear in the clusters. Table 8 lists the composition of item parcels, their difficulty (mean), and the variance of scores. Difficulty naturally varies widely among the parcels since they represent a sorting of items by difficulty. However, to the extent that the skewness of these distributions biases intercorrelations among item parcels, it should be in the direction of depressing the correlations among sets of items of different variance, rather than among sets of different difficulty. That is, if the factors to emerge were indeed spurious, we would expect one factor to consist of items of moderate difficulty and another to consist of items of low and high difficulty together. If, instead, we continued to obtain a factor consisting of easy items and another consisting of difficult items, we would be less inclined to think of these difficulty factors as artifactual and more inclined to invest them with substantive meaning.

The 53-item parcels were subjected to a principal components analysis. The largest eigenvalues were 33.289, 6.232, 3.664, 2.338, 1.617, 1.388, 1.094, 1.048, .905, and .808.

Although eight eigenvalues were greater than one, a scree test (Cattell, 1966) suggested that six factors would be appropriate. Three-, four-, and five-factor principal axis solutions were also rotated and examined before the final decision was made to base the description of the item parcels on the six-factor solution. A six-factor minres factoring, followed by varimax and oblimin rotations, and a weighted minres solution, followed by the hyperplane-oriented geoplane rotation, were performed. The several rotations yielded different descriptions of the covariance among clusters, and their results will be described in turn.

The minres solution resulted in a total communality of 21.85, or 90.4% of the common variance as estimated by the sum of Tucker's adjusted highest off-diagonal communality estimates. Orthogonal varimax rotation resulted in three substantial factors accounting for almost 80% of the common variance, and three smaller factors, each accounting for about 7% of the common variance (Table 9). These factors were generally comparable to those which emerged from the item-level analyses with an easy reading comprehension and

Table 8

Item-Parcel Designations and Their Means and Standard Deviations

Number	Name	Number of Items	Mean No. Correct	S.D.
1	SC (Easy)	4	2.98	1.04
2	SC (Easy)	4	2.95	1.06
3	SC (Difficult)	4	1.94	1.18
4	SC (Difficult)	4	1.39	1.24
5	AN (Easy)	4	1.80	1.25
6	AN (Easy)	4	3.28	.88
7	AN (Difficult)	4	.85	1.04
8	AN (Difficult)	4	.77	1.03
9	OPP (Very Difficult)	4	.52	.91
10	OPP (Difficult)	4	.93	1.02
11	OPP (Mid Difficult)	4	1.73	1.25
12	OPP (Easy)	4	1.85	1.35
13	OPP (Very Easy)	4	3.23	1.02
14	RCP 1	3	2.43	.80
15	RCP 2	3	1.74	.88
16	RCP 3 (Difficult)	4	2.20	1.37
17	RCP 3 (Easy)	3	2.87	1.19
18	RCP 4	4	1.47	1.03
19	RCP 5 (Difficult)	4	1.85	1.49
20	RCP 4 (Easy)	4	2.75	1.48
21	QC Choice D (Difficult)	3	.90	.88
22	QC Choice D (Easy)	3	1.77	.96
23	QC Choice A,B,C (Very Difficult)	4	1.13	1.08
24	QC Choice A,B,C (Difficult)	4	1.68	1.09
25	QC Choice A,B,C (Mid)	4	2.54	1.00
26	QC Choice A,B,C (Easy)	4	3.07	1.00
27	QC Choice A,B,C (Easy)	4	3.28	.96
28	QC Choice A,B,C (Very Easy)	4	3.70	.65
29	DI	4	2.96	1.10
30	DI Extraction	3	2.21	1.02
31	DI Manipulation	3	1.60	1.10
32	Q (Easy)	3	2.16	.79
33	GEOM	4	1.69	1.19
34	ALG	4	1.14	.98
35	Word Problems	4	1.94	.92
36	AX Choice A	4	2.95	1.01
37	AX Choice B	5	3.39	1.47
38	AX Choice C	4	2.10	1.27
39	AX Choice D	3	1.17	.98
40	AX Choice E	4	2.96	1.10

ALG = Algebra
AN = Analogies
AR = Analytical Reasoning
AX = Analysis of Explanations
DI = Data Interpretation
GEOM = Geometry
LD = Logical Diagrams
LR = Logical Reasoning
OPP = Opposites
QC = Quantitative Comparison
RCP(N) = Reading Comprehensive Passage (Number)

(Cont'd.)

Table 8

Item-Parcel Designations and Their Means and Standard Deviations

(Cont'd.)

Number	Name	Number of Items	Mean No. Correct	S.D.
41	AX Choice D	4	1.76	1.33
42	AX Choice C	3	1.65	1.14
43	AX Choice A,B,E	4	2.59	1.10
44	AX Choices A,B,E	4	2.36	1.30
45	AX Choice D	5	1.81	1.44
46	LD (Difficult)	4	1.74	1.21
47	LD (Mid Difficult)	3	1.77	1.13
48	LD (Mid Easy)	4	2.87	1.25
49	LD (Very Easy)	4	3.40	.91
50	AR (Set 1)	3	2.22	.89
51	LR	4	2.49	1.22
52	AR (Set 2)	4	2.84	1.43
53	AR (Set 3)	4	1.50	1.19

Table 9

Varimax Factor Loadings for Item-Parcel Analysis

Parcel Number	Parcel Code	Factor I	II	III	IV	V	VI	Communality
1	SC	54	20	33				46
2	SC	55		32				46
3	SC	37		48				43
4	SC	31		61				51
5	AN	36		55				47
6	AN	56						39
7	AN			69				54
8	AN			72				55
9	OPP			62				41
10	OPP			64				43
11	OPP	24		67				52
12	OPP	27		66				55
13	OPP	60		31				50
14	RCP1	58						41
15	RCP2	37	36					34
16	RCP3	46		30	22			37
17	RCP3	52		22	22			39
18	RCP4	37	21	32	29			38
19	RCP5	26		26	67			64
20	RCP5	33			68			66
21	QC		51					33
22	QC	25	57					42
23	QC		56					38
24	QC		49					25
25	QC		56					36
26	QC	30	55					39
27	QC	35	52					40
28	QC	30	44					30
29	DI	35	41			23		36
30	DI	25	26			55		46
31	DI		32			58		50
32	Q		50					29
33	GEOM		71					58
34	ALG		44			22		29

ALG = Algebra
AN = Analogies
AR = Analytical Reasoning
AX = Analysis of Explanations
DI = Data Interpretation
GEOM = Geometry
LD = Logical Diagrams
LR = Logical Reasoning
OPP = Opposites
QC = Quantitative Comparison
RCP(N) = Reading Comprehensive Passage (Number)
SC = Sentence Completion

Factors: I Verbal Reasoning II Quantitative III Vocabulary IV Technical Reading Comprehension V Data Interpretation VI Analytic

Note. Loadings less than .20, as well as all decimal points, have been omitted.

(Cont'd.)

Table 9

Varimax Factor Loadings for Item-Parcel Analysis

(Cont'd.)

Parcel Number	Parcel Code	Factor I	II	III	IV	V	VI	Communality
35	Word Problems	21	47			31		41
36	AX-A	48	21					30
37	AX-B	49	25				22	37
38	AX-C	37	24				23	27
39	AX-D	24	27	22			28	27
40	AX-E	48						32
41	AX-D	33	34	25			31	40
42	AX-C	41					29	31
43	AX	51					26	41
44	AX	36				33	30	41
45	AX-D	26	28	26		25	40	47
46	LD	35	36	23			30	41
47	LD	46	42				37	54
48	LD	52	44				30	57
49	LD	59	23					44
50	AR	26	34					21
51	LR	46	20	27				43
52	AR	35	24					26
53	AR	21	29			29	25	34
Common Variance		6.79	5.6[illegible]	[illegible]08	1.55	1.48	1.43	21.85

analytic item factor (I), a quantitative factor (II), and a difficult discrete verbal factor (III) comprising the major dimensions of the test. In contrast to the two difficulty-related quantitative factors obtained in the item-level analysis, only one general quantitative factor (II) emerged from this orthogonal rotation of parcel scores. Of the less prominent factors, one represented the technical comprehension passage (Factor IV), another data interpretation items (Factor V), and the final factor (VI) tapped aspects of the analytical items, particularly of those analysis of explanations items with choice D as the correct answer. Thus, only the easy quantitative factor and the least reliable analytic item factor pair (even-item Factor VI, odd-item Factor VIII) from the analysis of tetrachorics failed to appear in this analysis of item parcels. In spite of this general confirmation of the item-level findings, there are important differences. In the item-level analyses, most analytic items loaded higher on analytic factors than on the general reading comprehension factor. In the varimax item-parcel solution this is no longer the case, and Factor I must correctly be described as reading comprehension and analytic reasoning.

Partly because of the increased reliability of item parcels compared with items, not only the logical diagrams but also other analytic items show moderate loadings on the quantitative factor in this solution, making it appear that the analytic item type is essentially describable as a combination of V and Q, but not of vocabulary, and that these items show relatively little variance that could be described as unique to their item type.

The data interpretation factor (V) shows some relationship to word problems and to scattered analytic parcels. In the item-level results, the relationship to certain analytic items was evident, but the construct-validity-supporting relationship to individual word problems was not noted.

The varimax rotation of the factors based on item parcels thus yields three major factors, the first of which covaries strongly with easy verbal items, analytic items, and, even to a lesser extent, with easy quantitative items. This way of describing the structure of the test suggests that analytic items have more in common with this general comprehension factor than with the minor analytic factor, which accounts for only seven percent of the common variance of the test.

However, the restriction to orthogonal factors used in this rotation is clearly an oversimplification of the structure. The abilities underlying success on these item types are certainly not independent. Since it is probably unreasonable to expect these abilities to be uncorrelated, an oblique solution was obtained, using the oblimin criterion. As Harman (1976, p. 259) has pointed out, however, some simplicity of interpretation may be sacrificed when an oblique solution is employed, but this disadvantage may be offset by simpler descriptions of the variables in terms of correlated factors.

Table 10 gives the results (factor pattern) of this rotation, which shows many more near-zero loadings and many more high loadings, and Table 11 contains the factor structure. The analytic items have split off to form a major factor (VI) accounting for nearly 25% of the common variance, second only to that accounted for by the discrete verbal factor (III). The quantitative factor (II) and data interpretation factor (V) remain relatively unchanged, but the general reading comprehension factor (varimax Factor I) has been decimated, with most reading passage variance going to Factor IV, with highest loadings on the scientific/technical passage 5, and easy discrete verbal variance being spread across Factors I, III, and VI. The oblique Factor VI displays high correlation with all other factors except Factor I, as is shown in Table 12.

Factor IV, defined primarily by reading passages, particularly the technical passage, shows correlation with Factors III and V, vocabulary and data interpretation, as well as with the analytic factor (VI). Factor II, the quantitative factor, is related to data interpretation as well as to the analytic factor. The pattern of loadings on Factor I, positive on easy items of all types and near zero on difficult items, suggests that the rotation has turned what had been a general verbal and analytic factor in the varimax solution into a residual difficulty factor, assigning reading comprehension variance to Factor IV, analytic and some reading comprehension variance to Factor VI, and retaining only the easiest discrete verbal and passage one comprehension items on Factor I. Since it does not seem reasonable that easy antonyms (opposites) would load .39, but difficult antonyms -.14 (a loading that is not shown using our criteria of deleting loadings less than .20 in absolute value) on an important underlying ability, the preference is to conclude that the oblimin rotation tries too hard in its attempt to create distinct clusters. If, in fact, reading comprehension (RC) and analytic ability (A) are distinguishable but correlated factors as indicated in Figure 1 with items arrayed across the hyperplane according to their relative dependency on the two factors, the oblimin transformation appears to have placed Factor VI through the analytic side of the interior of the cluster rather than at the defining boundaries, and to have broken up residual reading variance into difficult passages (Factor IV) and a compensating or "suppressor" bipolar difficulty factor. This seems to us to be artificial and hardly a parsimonious description of the structure. If confronted with only these two solutions, the varimax solution, in which the correlated analytic and reading comprehension items are placed on a single verbal reasoning factor, and the oblimin solution, we would be more comfortable with the first.

Another oblique solution was considered, however. Yates' geoplane (1978) is an attempt to find simple structure via the approach of searching for hyperplanes (rather than for clusters) such that the factors determine hyperplane boundaries. By minimizing the geometric mean of squared loadings of variables on factors, the geoplane criterion

Table 10

Oblimin Factor Pattern for Item-Parcel Analysis
(partial correlations)

Parcel Number	Parcel Code	Factor I	II	III	IV	V	VI
1	SC	30		28			
2	SC	33		26			
3	SC			43			
4	SC			61			
5	AN			53			
6	AN	35					20
7	AN			73			
8	AN			76			
9	OPP			69			
10	OPP			69			
11	OPP			71			
12	OPP			70			
13	OPP	39		25			
14	RCP1	36					20
15	RCP2		29		20		
16	RCP3			21	27		
17	RCP3	27			27		
18	RCP4			21	34		
19	RCP5				83		
20	RCP5				85		
21	QC		44				
22	QC		51				
23	QC		50				
24	QC		52				
25	QC		55				
26	QC		54				
27	QC	21	53				
28	QC	22	45				
29	DI		32			24	
30	DI					64	
31	DI					66	
32	Q		50				
33	GEOM		66				
34	ALG		32			21	

ALG = Algebra
AN = Analogies
AR = Analytical Reasoning
AX = Analysis of Explanations
DI = Data Interpretation
GEOM = Geometry
LD = Logical Diagrams
LR = Logical Reasoning
OPP = Opposites
QC = Quantitative Comparison
RCC(N) = Reading Comprehensive Passage (Number)
SC = Sentence Completion

Factors: I Easy Items II Quantitative III Vocabulary IV Technical Reading Comprehension V Data Interpretation VI Analytic

Note. Coefficients less than .20, as well as all decimal points, have been omitted.

(Cont'd.)

Table 10

Oblimin Factor Pattern for Item-Parcel Analysis
(partial correlations)

(Cont'd.)

Parcel Number	Parcel Code	Factor I	II	III	IV	V	VI
35	Word Problems		33			32	
36	AX-A	22					32
37	AX-B						47
38	AX-C						40
39	AX-D						34
40	AX-E						42
41	AX-D						39
42	AX-C						48
43	AX						50
44	AX					33	38
45	AX-D	23				20	41
46	LD		20				44
47	LD		22				63
48	LD		27				60
49	LD	26					43
50	AR		24				
51	LR						30
52	AR						27
53	AR						
Common Variance		1.75	4.46	5.20	2.95	2.33	5.16

Table 11

Oblimin Factor Structure for Item-Parcel Analysis
(zero-order correlations)

Parcel Number	Parcel Code	Factor I	II	III	IV	V	VI
1	SC	44	35	50	46	39	53
2	SC	47	29	48	47	38	51
3	SC	25	31	60	47	33	48
4	SC	22	28	70	44	32	43
5	AN	29	26	65	47	31	41
6	AN	[illegible]	29	36	42	34	49
7	AN		25	73	37	26	35
8	AN			73	37	20	27
9	OPP			62	21		23
10	OPP			65	30		23
11	OPP		22	72	38	22	33
12	OPP		27	73	38	34	41
13	OPP	53	27	48	50	35	51
14	RCP1	49	25	36	45	30	49
15	RCP2	26	46	35	44	34	46
16	RCP3	34	23	45	50	27	47
17	RCP3	42	22	39	51	33	47
18	RCP4	24	33	47	55	33	47
19	RCP5		29	41	80	38	38
20	RCP5		23	34	80	43	39
21	QC		54	24	22	31	38
22	QC		62	24	28	37	47
23	QC		58	28	25	31	37
24	QC		49			21	21
25	QC		59	26	27	33	37
26	QC	21	60	21	29	33	42
27	QC	28	58		28	30	43
28	QC	26	49		21	30	34
29	DI	25	50	27	37	47	43
30	DI		35	25	38	67	35
31	DI		40	26	36	70	33
32	Q		53		22	32	30
33	GEOM		73	30	28	45	40
34	ALG		47	22	28	41	34

ALG = Algebra
AN = Analogies
AR = Analytical Reasoning
AX = Analysis of Explanations
DI = Data Interpretation
GEOM = Geometry
LD = Logical Diagrams
LR = Logical Reasoning
OPP = Opposites
QC = Quantitative Comparison
RCP(N) = Reading Comprehensive Passage (Number)
SC = Sentence Completion

Factors: I Essay Items II Quantitative III Vocabulary IV Technical Reading Comprehension V Data Interpretation VI Analytic

Note. Coefficients less than .20, as well as all decimal points, have been omitted.

(Cont'd.)

Table 11

Oblimin Factor Structure for Item-Parcel Analysis
(zero-order correlations)

(Cont'd.)

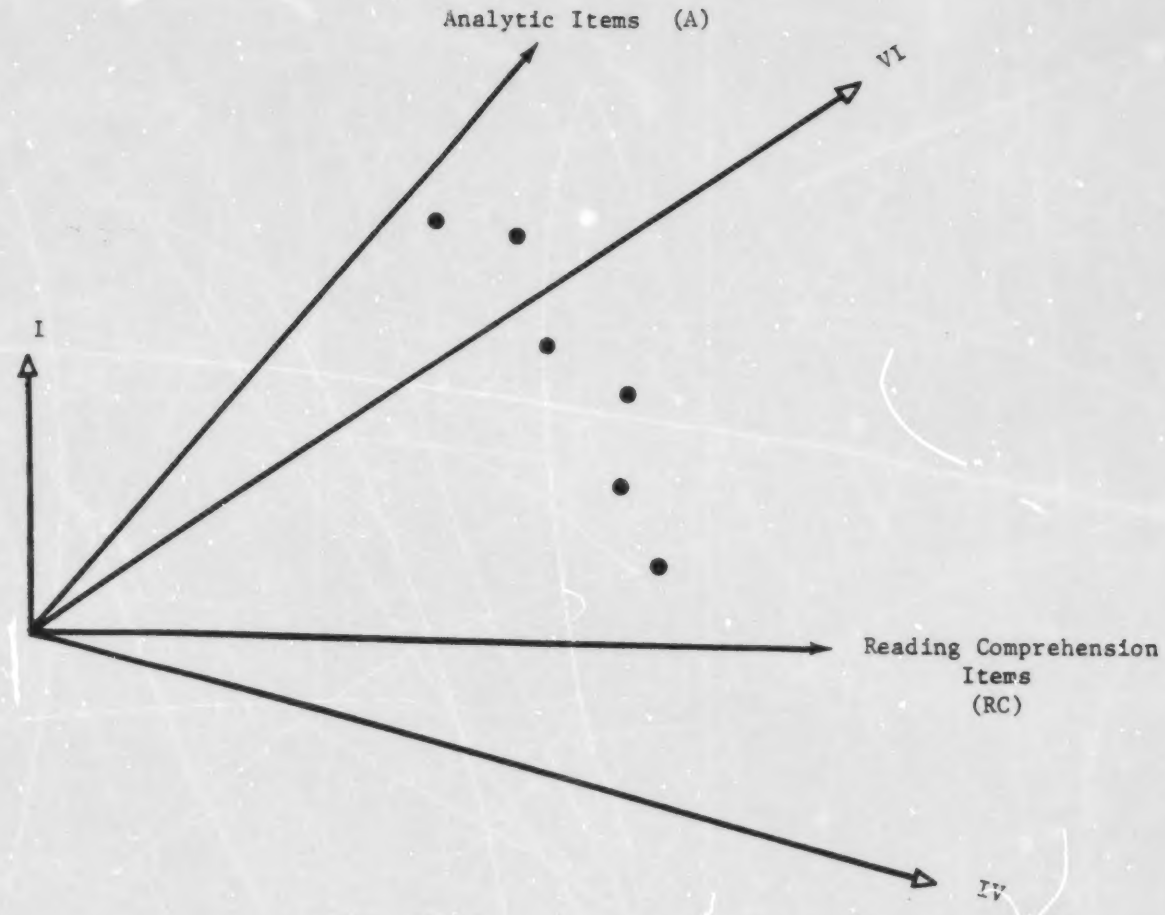
Parcel Number	Parcel Code	Factor I	II	III	IV	V	VI
35	Word Problems		54	31	36	54	43
36	AX-A	35	32	28	33	32	50
37	AX-B	30	37	28	35	36	59
38	AX-C		33	30	34	26	51
39	AX-D		35	35	35	29	47
40	AX-E	32	30	27	32	33	53
41	AX-D		44	42	44	39	58
42	AX-C	20	26	29	38	32	54
43	AX	29	31	32	41	43	61
44	AX		29	35	46	53	55
45	AX-D		38	43	49	50	58
46	LD		46	40	39	32	60
47	LD	20	53	36	38	35	71
48	LD	28	56	33	38	36	72
49	LD	43	36	33	40	35	61
50	AR		40		28	32	39
51	LR	28	34	45	52	44	57
52	AR	20	33	24	39	38	46
53	AR		37	34	41	49	45

Table 12

Oblimin Factor Correlations

Factor	I	II	III	IV	V
II	.08				
III	.15	.30			
IV	.26	.33	.51		
V	.13	.47	.33	.50	
VI	.33	.53	.46	.55	.49

Factors:
I Easy Items
II Quantitative
III Vocabulary
IV Technical Reading Comprehension
V Data Interpretation
VI Analytic



Oblimin Factors: I Easy Items
IV Technical Reading Comprehension
VI Analytic and Reading Comprehension

Figure 1. Hypothesized Analytic and Reading Item Structure and Oblimin Factors

allows variables to be factorially complex, but demands that each have a near-zero loading on at least one factor. That is, geoplane requires that each variable lie in a hyperplane not containing some factor. Faced with a situation as in Figure 1, this transformation is designed to find vectors A and RC, if they exist, rather than to represent their hyperplane with a cluster vector.

The geoplane program (Yates, 1978) begins with a weighted minres solution, weighting variables inversely by their communalities. This procedure made little difference in the initial factor matrix, but did slightly downplay "doublets," such as the technical passage 5 and data interpretation clusters, fitting them only if they also shared variance with other items.

The results of the geoplane rotation of six factors are given in Table 13. Geoplane factors have been labeled with primes (e.g., Factor I′) to help the reader in distinguishing between these and other factors. Here we see a reading comprehension factor with large loadings on reading passages, easier sentence completions, and easy discrete verbal items. Although a negative and several near-zero loadings on difficult verbal items remain, the factor accounts for 18.3% of the common variance and is clearly identifiable with easy reading comprehension. Factor II′, quantitative ability, has high loadings from all but the easiest quantitative and data interpretation clusters, and small loadings from passage 2, from difficult logical diagrams, and the first analytic reasoning parcel. This factor accounts for 22.8% of the common variance.

Factor III′, discrete verbal ability, includes difficult sentence completions and analogies, and all but the easiest parcel of antonyms, and accounts for 21.1% of the common variance.

Factor IV′, analytic items, receives its highest loadings from logical diagrams parcels, followed by analysis of explanations items in which choice B is the keyed response. Choice A analysis of explanations items are characterized as complex, sharing some variance with general reading comprehension. The fact that these items require the examinee to determine only that a statement is inconsistent with something stated in the passage makes the variance shared with reading comprehension seem quite reasonable. The first two clusters of choice D items also show small loadings on the quantitative factor, whereas the final set of analysis of explanation items have their highest loadings on Factor V′. Factor IV′ accounts for 18.4% of the common variance.

Factor V′, accounting for 11.9% of the common variance, combines the data interpretation and technical reading clusters, which were assigned to separate factors by the varimax and oblimin solutions, and reintroduces the analytic speed component of this factor, which emerged in Factor VI′ of the item-level analysis of odd items, but which was less prominent in the varimax or oblimin cluster solutions. Finally, geoplane Factor VI′ is

Table 13

Geoplane Factor Pattern for Item-Parcel Analysis
(partial correlations)

Parcel Number	Parcel Code	Factor I′	II′	III′	IV′	V′	VI′
1	SC	47					
2	SC	54					
3	SC	36		30			
4	SC			57			
5	AN	38		42			
6	AN	47					
7	AN			72			
8	AN			70			
9	OPP	-25		70			
10	OPP			65			
11	OPP	22		65			
12	OPP			72			
13	OPP	67					
14	RCP1	59					
15	RCP2	43	33				
16	RCP3	53					
17	RCP3	60					
18	RCP4	49					
19	RCP5	37				31	
20	RCP5	42				41	
21	QC						
22	QC		50				
23	QC		63				
24	QC		59				
25	QC		51				
26	QC		36				27
27	QC		30				31
28	QC						55
29	DI	22					25
30	DI					46	
31	DI					43	
32	Q		38				30
33	GEOM		70				

ALG = Algebra
AN = Analogies
AR = Analytical Reasoning
AX = Analysis of Explanations
DI = Data Interpretation
GEOM = Geometry
LD = Logical Diagrams
LR = Logical Reasoning
OPP = Opposites
QC = Quantitative Comparison
RCP(N) = Reading Comprehensive Passage (Number)
SC = Sentence Completion

Factors: I′ Reading Comprehension II′ General Quantitative III′ Vocabulary IV′ Analytic V′ Data Interpretation and Technical Comprehension VI′ Easy Quantitative

Note. Loadings less than .20, as well as all decimal points, have been omitted.

(Cont'd.)

Table 13

Geoplane Factor Pattern for Item-Parcel Analysis
(partial correlations)

(Cont'd.)

Parcel Number	Parcel Code	Factor I′	II′	III′	IV′	V′	VI′
34	ALG		43			21	
35	Word Problems		38			23	
36	AX-A	27			23		
37	AX-B				44		
38	AX-C				30		
39	AX-D				24		
40	AX-E	23			34		
41	AX-D		22		31		
42	AX-C				38		
43	AX				38		
44	AX				29	43	
45	AX-D				32	39	
46	LD		26		38		
47	LD		21		54		
48	LD				53		
49	LD	32			35		
50	AR		27				
51	LR	34			21	20	
52	AR	21				22	
53	AR				20	46	

characterized by the easiest quantitative items, and corresponds to Factor IV in both item-level analyses. This factor was not found in the cluster oriented solutions, which could better satisfy their optimization criteria by separating data interpretation and technical passage 5 clusters. Factor VI accounts for 7.3% of the common variance.

The geoplane analysis of item parcels thus agrees closely with the two item-level analyses of tetrachorics, differing primarily in (a) assigning data interpretation items, technical reading passage 5, and the final analysis of explanations item set to a single factor; (b) in grouping analytic items together with less differentiation in terms of response choices, and (c) in assigning less variance to the easy quantitative factor. (It should be noted that the final analysis of explanations item set is based on a passage about hospital statistics, appearing on the surface to be somewhat similar to both data interpretation items and to the technical reading paassage.) The intercorrelations of the geoplane factors (Table 14) show a strong relationship (r = .66) between the reading comprehension and analytic factors, and high correlations (.54 and .56) between quantitative and analytic and between reading comprehension and vocabulary factors. Although correlated, the factors are distinct in interpretation, and the geoplane solution generally confirms that the structure apparent in the analyses of item-level tetrachorics may also be found in the matrix of Pearson correlations of the more reliable parcel scores.

In summary, if one wishes to describe the structure of item parcels in terms of orthogonal factors, it appears that analytic items are primarily explained by a factor related both to reading comprehension and quantitative ability. However, if one allows correlated factors, the geoplane rotation identifies a distinct, although strongly correlated, factor that differentiates analytic ability from reading comprehension. This latter interpretation leaves open the possibility that analytic and reading comprehension scales may yield differential predictive validity. The description in terms of orthogonal factors masks this possibility.

In either description, very easy analysis of explanations items (answer choice A, "inconsistent with or contradictory to," and answer choice E, "irrelevant to") seem to measure little beyond reading comprehension, whereas answer choices B, C, and D, logical diagrams and analytic reasoning items, appear to be responsible for measuring whatever distinctly analytical abilities are being assessed.

It is important to remember that correlated factors are involved here and that high factor pattern loadings represent those components of item variance unique to a factor. In an oblique solution, variables may show higher pattern coefficient loadings on one factor, although having higher correlations (factor structure coefficients) with another. Indeed, in the case of the geoplane solution, this phenomenon occurred with the reading passages. Table 15 gives the geoplane factor structure,

Table 14

Geoplane Factor Correlations

Factor	I′	II′	III′	IV′	V′
II′	.42				
III′	.56	.37			
IV′	.66	.54	.38		
V′	.51	.50	.41	.42	
VI′	.34	.36	-.02	.40	.21

Factors:
- I′ Reading Comprehension
- II′ Quantitative
- III′ Vocabulary
- IV′ Analytic
- V′ Data Interpretation and Technical Comprehension
- VI′ Easy Quantitative

Table 15

Geoplane Factor Pattern for Item-Parcel Analysis
(zero-order correlations)

Parcel Number	Parcel Code	Factor I′	II′	III′	IV′	V′	VI′	Communality
1	SC	44	37	44	49	37	28	44
2	SC	44	31	43	47	37	24	44
3	SC	44	38	56	44	38		44
4	SC	52	34	69	40	37		52
5	AN	47	32	62	37	36		47
6	AN	37	29	32	46	31	32	37
7	AN	56	33	75	33	33		56
8	AN	51	23	71	25	30		51
9	OPP	40	24	62	24	24		40
10	OPP	42	20	64	22	23		42
11	OPP	54	29	72	30	27		54
12	OPP	59	32	75	39	38		59
13	OPP	49	30	43	46	34	25	49
14	RCP1	39	26	32	45	29	27	39
15	RCP2	36	48	31	42	34	26	36
16	RCP3	37	27	41	43	33		37
17	RCP3	39	25	34	41	37	20	39
18	RCP4	39	39	44	42	40		39
19	RCP5	38	35	40	35	52		38
20	RCP5	41	27	32	36	56		41
21	QC	35	58	22	36	28		35
22	QC	43	62	21	46	32	40	43
23	QC	40	63	26	35	31		40
24	QC	27	50					27
25	QC	37	59	24	35	30	36	37
26	QC	37	52		41	30	45	37
27	QC	37	49		43	26	49	37
28	QC	39	37		35	24	59	39
29	DI	37	48	24	40	41	43	37
30	DI	35	36	23	34	55	32	35
31	DI	34	44	25	32	55	24	34
32	Q	31	49		29	29	41	31
33	GEOM	59	75	28	37	42	36	59
34	ALG	30	51	20	31	40		30

ALG = Algebra
AN = Analogies
AR = Analytical Reasoning
AX = Analysis of Explanations
DI = Data Interpretation
GEOM = Geometry
LD = Logical Diagrams
LR = Logical Reasoning
OPP = Opposites
QC = Quantitative Comparison
RCP(N) = Reading Comprehensive Passage (Number)
SC = Sentence Completion

Factors: I′ Reading Comprehension II′ General Quantitative III′ Vocabulary IV′ Analytic V′ Data Interpretation and Technical Comprehension VI′ Easy Quantitative

Note. Coefficients less than .20, as well as all decimal points, have been omitted.

(Cont'd.)

Table 15

Geoplane Factor Pattern for Item-Parcel Analysis
(zero-order correlations)

Parcel Number	Parcel Code	Factor I′	II′	III′	IV′	V′	VI′	Communality
35	Word Problems	39	57	28	40	48	31	39
36	AX-A	29	31	26	48	27	33	29
37	AX-B	38	36	24	60	31	34	38
38	AX-C	27	37	28	48	27		27
39	AX-D	25	40	32	43	32		25
40	AX-E	30	31	24	52	27	28	30
41	AX-D	39	49	39	55	41	20	39
42	AX-C	29	30	26	51	35		29
43	AX	38	34	29	57	40	29	38
44	AX	41	35	32	50	57	23	41
45	AX-D	45	46	40	52	58		45
46	LD	41	50	36	58	35	20	41
47	LD	52	53	32	69	35	34	52
48	LD	57	53	29	72	33	44	57
49	LD	45	34	29	60	30	40	45
50	AR	22	41		37	29	24	22
51	LR	44	39	41	54	49	20	44
52	AR	27	34	21	43	41	25	27
53	AR	38	42	32	42	58		38
Common Variance		3.52	4.39	4.06	3.54	2.29	1.41	19.21

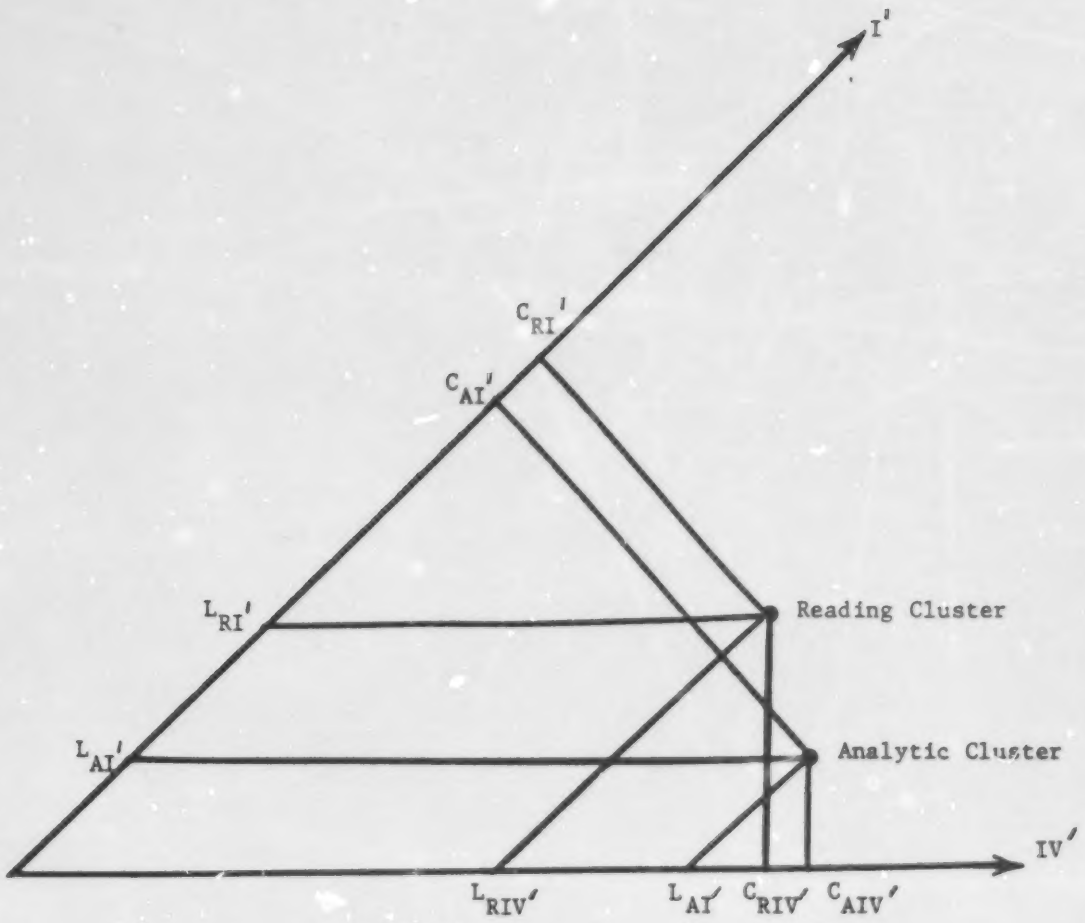
showing correlations of the factors with the item parcels. Although reading passages displayed high loadings or partial correlations with Factor I′ and near-zero loadings on Factor IV′, examination of orthogonal projections of the variables on the factors reveals that reading passages are slightly closer to Factor IV′ than to Factor I′. Figure 2 is a partial illustration of the situation. In the figure, variables R and A both show higher correlations with Factor IV′ than with Factor I′, but variable R has a high loading on Factor I′, and variable A has a high loading on Factor IV′. This is only a partial illustration of the present situation since it does not include correlated Factors III′ and V′, which take up further non-Factor I′ components of the variance of R, and decrease its loading on Factor IV′ to near zero.

Thus, although Factor I′ represents the dimension unique to reading items, it does not necessarily represent a typical reading item. The item parcel relatively nearest to Factor I′ consists of very easy antonyms, with loadings of .67 on Factor I′, .07 on Factor III′, and no more than .03 on other factors. Yet, the correlations of this parcel with Factors I′, III′, and IV′ are .49, .43, and .46, respectively. Eight other item parcels--sentence completion 4, antonyms 11 and 12, logical diagrams 47 and 48, and even geometry parcel 33--have higher correlations with Factor I′ than does this easy antonym parcel, and considerably higher correlations than does any reading passage. However, because these eight parcels all show correlations of about .7 with other factors, their loadings on Factor I′ are negligible, leaving only easy discrete verbal and reading comprehension passages with high loadings on the factor. Thus the orthogonal varimax result, in which reading comprehension and analytic items loaded on a single general verbal reasoning factor, is not inconsistent with the geoplane description. Indeed, the pattern of correlations of geoplane Factors I′ and IV′ are both generally similar to that of the varimax verbal reasoning factor, the major difference being in the lower loadings of the latter on quantitative item parcels. Geoplane Factor I′ is seen to be more closely correlated with discrete verbal items and less with analytic items than is analytical Factor IV′.

If the varimax general factor is thought of as near the centroid of geoplane Factors I′ and IV′, the minor varimax Factor VI′ picking out a dimension of analytic variation orthogonal to reading, quantitative ability, and most analytic variance may be thought of as representing a dimension of contrast between the geoplane reading and analytic factors, as in Figure 3.

Thus, geoplane Factor IV′ is not closely related to varimax Factor VI′, in spite of the fact that both tap aspects of analytic ability.

To further assist in describing the structure of the correlated factors, a second-order principal components analysis was performed on the matrix of factor intercorrelations (Table 14). The first 3 eigenvalues were 3.08, 1.06 and .65. Table 16 gives the loadings of the factors on the principal components.



Geoplane Factors: I' Reading Comprehension, IV' Analytic

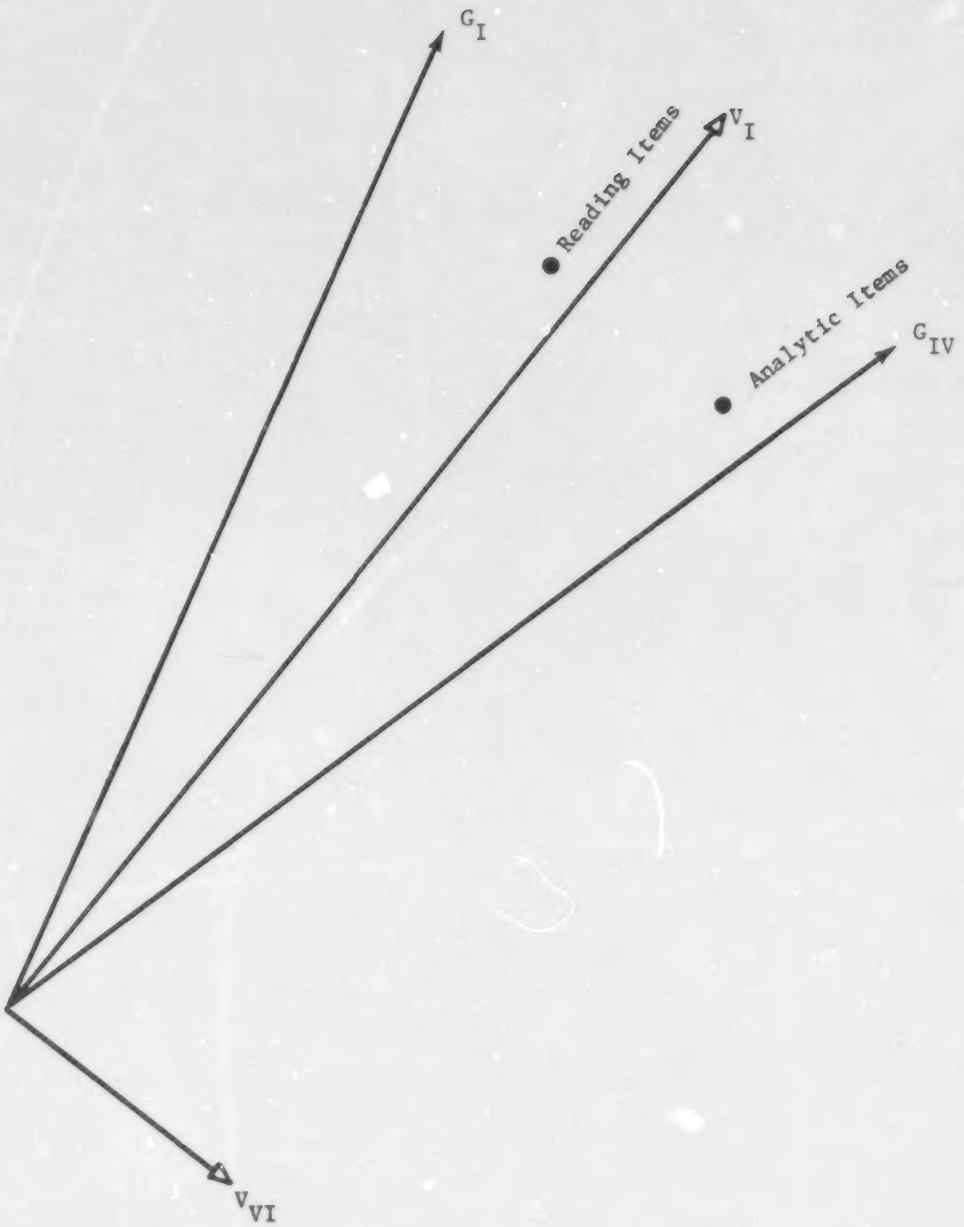
$C_{RI'}$: Correlation of Reading Cluster with Factor I'

$C_{RIV'}$: Correlation of Reading Cluster with Factor IV' $C_{RIV'} > C_{RI'}$

$L_{AI'}$: Loading (partial correlation) of Analytic Cluster on Factor I'

$L_{RI'}$: Loading (partial correlation) or Reading Cluster on Factor I' $L_{RI'} > L_{AI'}$

Figure 2. Structure Correlations and Pattern Loadings for Correlated Factors



Factors: G_I Geoplane Reading Comprehension
G_{IV} Geoplane Analytic
V_I Varimax Verbal Reasoning
V_{VI} Varimax Analytic

Figure 3. Relationship of Geoplane and Varimax Reading and Analytic Factors

Table 16

Principal Components of Geoplane Factors

	Component					
Factor	1	2	3	4	5	6
I′	.84	.11	.36	-.20	.04	.35
II′	.72	-.13	-.43	.46	-.02	.16
III′	.64	.60	.17	.14	-.38	-.17
IV′	.81	-.16	.26	.15	.41	-.24
V′	.72	.17	-.48	-.45	.08	-.09
VI′	.48	-.78	.09	-.13	-.35	-.09

Factors:
- I′ Reading Comprehension
- II′ Quantitative
- III′ Vocabulary
- IV′ Analytic
- V′ Data Interpretation and Technical Comprehension
- VI′ Easy Quantitative

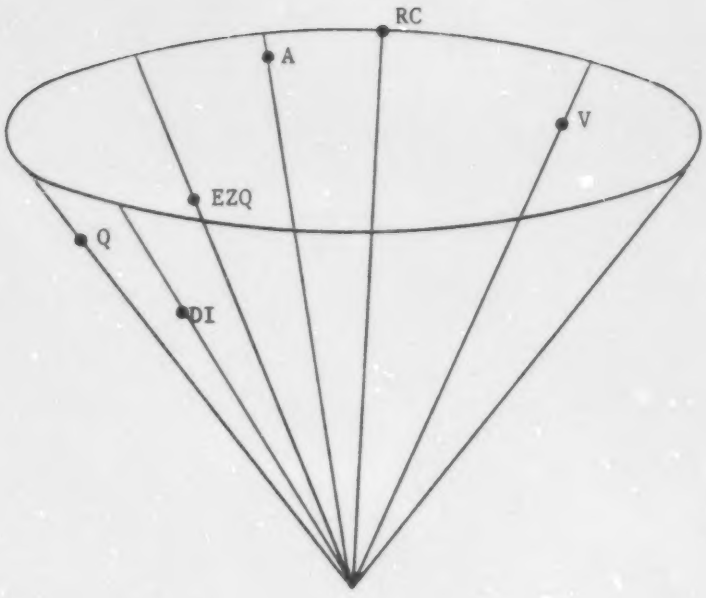
Here, the first component, represents the general ability common to all the factors. The reading comprehension and analytic factors show highest loadings on this first component, and the lower variance vocabulary and easy quantitative factors have lowest loadings. The second principal component contrasts the difficult vocabulary factor with the easy quantitative factor, but the small positive loading on reading comprehension and data interpretation and the negative loadings on the quantitative factors and analytic factors suggest that this component is not simply a difficulty dimension. The third component contrasts quantitative and data intrepretation factors with reading comprehension and analytic variance. The remaining components serve largely to further differentiate quantitative factors from the data interpretation factor, the analytic from the vocabulary factor, and the analytic from the reading comprehension factor. Figure 4 represents the factors in the space of the first three components, picturing the factors on a cone around the first principal component. The distribution near the circumplex around the cone again shows the analytic factor nearer the reading comprehension portion of the circumplex than the analytic portion, and shows a gap between the data interpretation and vocabulary portions, reflecting the fact that the test specifications do not include items that require both difficult vocabulary and quantitative ability. (Such items might be more appropriate for achievement tests in technical fields.)

This three-dimensional representation again suggests that, to a first approximation, the analytic factor can be described as a linear combination of V and Q, with V given a larger weight. It is only in components 5 and 6, which together account for less than 5% of the total variance of the factor intercorrelations, that the analytic factor is sharply differentiated from the others.

Relationship of Evaluation of Evidence Items to the Restructured Test

Since evaluation of evidence items are still under consideration for inclusion in future forms of the test, their relationship to factors found in the restructured test was considered through factor extension analysis. Both the varimax and the geoplane factor solutions were extended in order to determine the loadings of analysis of explanations and evaluation of evidence parcels on these factors. These analyses were intended to shed light on the effects of adding evaluation of evidence items to the current, restructured Aptitude Test.

Table 17, which shows the results of the extension of orthogonal factors, suggests that evaluation of evidence items are much more highly related to Factor I, reading comprehension, than to Factor VI, the analytical factor defined by analysis of explanation items and, to some extent, by logical diagram and analytical reasoning items. All of the loadings of evaluation of evidence parcels on the reading comprehension factor are substantial, but these parcels did not have any large loadings on the analytical factor, although they did have some modest loadings on other factors.



Geoplane Factors: V, Vocabulary; RC, Reading Comprehension;
A, Analytic; EZQ, Easy Quantitative;
Q, Quantitative; DI, Data Interpretation

Figure 4. Circumplex Structure: Principal Components of Geoplane Factors

Table 17

Factor Extension Loadings of Analytical Parcels and Evaluation of Evidence Parcels on Operational Form Varimax Factors

Item Type	Factor I	II	III	IV	V	VI
AX (Passage 1)	54	33				43
AX (Passage 2)	71	24				35
AX (Passage 3)	58	25	20			59
AX (Passage 4)	33	20	23	20	46	61
AX (Choice A)	64				23	22
AX (Choice B)	60	24			24	43
AX (Choice C)	48	20				53
AX (Choice D)	29	37	32	20		61
AX (Choice E)	55				30	36
AX (Easy)	76	25			25	44
AX (Difficult)	45	33	29			70
Logical Diagrams	64	48				49
Analytical Reasoning	26	40			37	34
Logical Reasoning	49		27	20	21	22
EE (Choice A)	45				29	
EE (Choice B)	44					
EE (Choice B)	36				24	
EE (Choice C)	51	22				
EE (Choice D)	44		20			
EE (Choice E)	50					
EE (Choice E)	50			20	29	
EE (Set 1)	57					
EE (Set 2)	48	25	24	21		
EE (Set 3)	52	22		23	22	
EE (Set 4)	40				36	
EE (Very Difficult)	44	20	23	21		
EE (Difficult)	56	27	21	23	20	
EE (Easy)	56	20			21	
EE (Very Easy)	54				36	

AX = Analysis of Explanations
EE = Evaluation of Evidence

Factors: I Verbal Reasoning II Quantitative III Vocabulary IV Technical Reading Comprehension V Data Interpretation VI Analytic

Note. Loadings less than .20, as well as all decimal points, have been omitted.

The sole logical reasoning parcel also had a higher loading on the reading comprehension factor than on the analytical factor.

The structure correlations (Table 18) resulting from the extension of oblique geoplane solution also suggested that evaluation of evidence items are more closely associated with reading comprehension ability (Factor I′) than with analytical ability (Factor IV′) in the geoplane solution. Table 18, containing the correlations of geoplane factors with extension variables, shows that for every evaluation of evidence subscore, correlations were higher with reading comprehension than with analytical ability.

Table 19, which shows loadings of extension variables on the geoplane factors, indicates clearly that when correlations among factors are considered, reading comprehension is more clearly associated with performance on evaluation of evidence items than is analytical ability of the type defined by analysis of explanations and logical diagram items.

In summary, it appears that adding items of the evaluation of evidence type to the restructured Aptitude Test as it now stands would add very little to the measurement of the type of analytical ability now measured by the test. Rather, dimensions found in the verbal and quantitative sections of the test, particularly reading comprehension ability, seem to underlie performance on this item type. Replacing analysis of explanations items with evaluation of evidence items would have the likely effect of drawing the analytical and verbal factors even closer together. Such action would, therefore, seem inadvisable.

Extension of Item-parcel Factors into Background Variables

All GRE candidates are requested to fill out an information questionnaire reporting sex, ethnicity, undergraduate major, intended graduate major, average grades, and information concerning extracurricular activities (Altman, 1977).

The technique of factor extension analysis (Dwyer, 1937; Harman, 1938) was employed to determine the relationships of the item-parcel factors to variables derived from the informtion questionnaire. Although such variables as intended major field and self-reported grade point average cannot provide evidence of predictive validity, the patterns of extension correlations and pattern coefficients can give evidence regarding construct validity. This section addresses the extent to which factors show patterns of loadings consistent with the interpretations placed upon them in light of what is known concerning the relationships of such abilities to student characteristics.

Both the orthogonal varimax and the oblique geoplane item-parcel solutions were extended into the space of the questionnaire variables. Because the geoplane solution gave a clearer distinction among verbal, analytic, and quantitative factors, it will be examined first for evidence for and against construct validity, and the results will then be contrasted with those deriving from the varimax extension.

Table 18

Correlations of Extension Variables (Parcels) with Geoplane Factors
(zero-order correlations)

Item Type	Factor I′	II′	III′	IV′	V′	VI′
AX (Passage 1)	58	80	37	51	34	29
AX (Passage 2)	66	85	31	41	34	41
AX (Passage 3)	64	89	42	50	56	23
AX (Passage 4)	48	68	43	44	84	18
AX (Choice A)	62	68	32	32	43	43
AX (Choice B)	56	81	31	39	49	42
AX (Choice C)	52	75	32	41	42	
AX (Choice D)	51	72	49	61	58	
AX (Choice E)	51	6	27	29	45	30
AX (Easy)	73		37	45	54	47
AX (Difficult)	61	89	51	61	66	
Logical Diagrams	64	99	39	62	33	43
Analytical Reasoning	42	53	31	56	71	23
Logical Reasoning	65	56	41	39	54	
EE (Choice A)	54	43	27	29	51	32
EE (Choice B)	50	43	25	26	28	25
EE (Choice B)	46	37	26	25	44	20
EE (Choice C)	61	52	32	36	46	33
EE (Choice D)	56	47	33	33	44	23
EE (Choice E)	56	46	24	32	35	30
EE (Choice E)	61	51	33	34	56	28
EE (Set 1)	59	52	24	29	35	36
EE (Set 2)	63	50	37	41	42	25
EE (Set 3)	65	53	34	39	52	28
EE (Set 4)	48	41	27	23	55	28
EE (Very Difficult)	58	46	36	36	43	20
EE (Difficult)	69	58	38	45	54	32
EE (Easy)	62	55	30	34	47	37
EE (Very Easy)	59	48	28	26	57	36

AX = Analysis of Explanations
EE = Evaluation of Evidence

Factors: I′ Reading Comprehension II′ Quantitative III′ Vocabulary
IV′ Analytic V′ Data Interpretation and Technical Comprehension,
VI′ Easy Quantitative

Note. Coefficients less than .20, as well as all decimal points, have been omitted.

Table 19

Loadings of Extension Variables (Parcels) on Geoplane Factors
(partial correlations)

Item Type	Factor I	II	III	IV	V	VI
AX (Passage 1)		48				
AX (Passage 2)		52				
AX (Passage 3)		58				
AX (Passage 4)		43			63	
AX (Choice A)		33				
AX (Choice B)		54			21	
AX (Choice C)		52				
AX (Choice D)		42			21	24
AX (Choice E)		44			21	
AX (Easy)		57				
AX (Difficult)		57			28	21
Logical Diagrams		64				
Analytical Reasoning					46	
Logical Reasoning	26				21	
EE (Choice A)	21				27	
EE (Choice B)	24					
EE (Choice B)					24	
EE (Choice C)	26					
EE (Choice D)	23					
EE (Choice E)	30					
EE (Choice E)	24				28	
EE (Set 1)	28					
EE (Set 2)	31					
EE (Set 3)	30					
EE (Set 4)					38	
EE (Very Difficult)	28					
EE (Difficult)	30					
EE (Easy)	25					
EE (Very Easy)	22				35	

Key: AX = Analysis of Explanations
EE = Evaluation of Evidence

Factors: I Reading Comprehension II Quantitative III Vocabulary
IV Analytic V Data Interpretation and Technical Comprehension,
VI Easy Quantitative

Table 20 gives the combinations of background variables from the questionnaire that were employed in the extension analysis. In addition to the global categories of Humanities, Social Sciences, Biological Sciences, and Physical Sciences on the questionnaire, subgroupings of intended graduate major fields were created. These groupings represent a trade-off between the fine level of detail available in individually coded fields and the necessity of having a reasonably large number of subjects in each group. For example, in examining an analytical reasoning factor it would have been clearly desirable to break out philosophy as a separate category. However, this was precluded by the small number of philosophy candidates in the sample. Instead, the Humanities category was broken down into language-related majors, including English, Speech, Foreign Languages, Linguistics, and Comparative Literature; a Music, Fine Arts, and Dramatic Arts category; and an Other Humanities category, which included Philosophy, and also Religion, Archaeology, and Art History. One could make a case for removing History from the Social Sciences category and adding to it this last cluster, further diluting the number of Philosophy majors. This was not done. Similarly, although the factor patterns for those who intend to enter law are of interest, their small numbers are lost among business, social work, and public administration majors in the "professional" category, as are those of medical doctors in the "Health" category. The "Applied Social Sciences" category consists predominantly of education, physical education, and educational administration majors. The following categories are relatively more homogeneous than are the other categories: the Basic Social Sciences, including Psychology, Political Science, and Economics; the Basic Biological Sciences; Mathematics/Physics, including Computer Science; Engineering; and Agriculture, Nutrition, Home Economics, as well as Applied Social Science (education). Hence these categories are more easily interpretable in their relationships than are the Professional, Health, or Other Humanities clusters. These categories differ slightly from those employed by Altman (1977), principally in breaking humanities into two groups--language and "other"--in placing Physics with Mathematics rather than with Chemistry, Entomology with Biological Sciences rather than with Agriculture, and Architecture and Urban Development with the Social Science professions. Communications and Library Science were included in an applied Social Science category with Education.

Table 21 gives the extension correlations for the geoplane solution. These correspond to a factor structure in that they are not affected by the intercorrelations among the factors. Inspection of the table shows that Factor IV′, analytic ability, shows the highest correlation with grades and with grades in major field (averaged over all fields) followed by Factor I′, reading comprehension. Factor II′, quantitative ability, Factor III′, vocabulary, and Factor V′, data interpretation, show lower correlations with grades, and the minor easy quantitative factor VI′ shows smallest correlations with undergraduate grades.

Table 20

Groups of Disciplines Used as Major Fields

Arts: Drama, Fine Art, Music

Language: Classical Languages, Comparative Literature, English, Far Eastern Languages, French, German, Italian, Linguistics, Near Eastern Languages, Russian, Spanish, Speech, other Foreign Languages

Other Humanities: Archaelogy, Art History, Philosophy, Religion, other Humanities

Basic Social Sciences: American Studies, Anthropology, Economics, Geography, History, Political Sciences, Psychology, Slavic Studies, Social Psychology, Sociology

Social Science Professions: Architecture, Business, Industrial Relations, Journalism, Law, Public Administration, Social Work, Urban Development

Applied Social Science: Communication, Education, Educational Administration, Guidance, Library Science, Physical Education

Basic Biological Sciences: Biochemistry, Biology, Biophysics, Botany, Entomology, Genetics, Microbiology, Zoology, other Biology

Health: Anatomy, Audiology, Bacteriology, Dentistry, Hospital Administration, Medicine, Nursing, Occupational Therapy, Optometry, Osteopathy, Parasitology, Pathology, Pharmacy, Physical Therapy, Physiology, Public Health, Veterinary Medicine

Applied Biological Science: Agriculture, Forestry, Home Economics, Nutrition

Mathematics/Physics: Applied Mathematics, Mathematics, Computer Science, Physics, Statistics

Chemistry/Earth Science: Astronomy, Chemistry, Geology, Metallurgy, Mining, Oceanography

Engineering: Aeronautical Engineering, Chemical Engineering, Civil Engineering, Electrical Engineering, Industrial Engineering, Mechanical Engineering, other Engineering

Note. Fields with the largest number of candidates within groupings are underlined.

Table 21

Geoplane Extension Mean Standard Differences
(zero-order divided by $\sqrt{pq}$)

Background Variable	Factor I′	II′	III′	IV′	V′	VI′
Sex (Male = 1, Female = 0)	-.034	.324	.004	.027	.078	.201
English	.370	.026	.104	.237	.140	.058
Major Grade	.285	.238	.246	.315	.233	.136
All Grade	.275	.227	.226	.308	.201	.153
Degree Objective	.208	.254	.234	.218	.138	.109
Student Government	.003	.018	-.017	.027	.015	.048
Preprofessional Achievement	.043	.054	.060	.026	.057	.28
Community Service	-.040	-.085	-.021	-.057	-.102	-.093
Literary	.069	-.011	.122	.030	-.023	-.073
Artistic	.074	.000	.026	.030	-.009	-.021
Und Humanities	.121	-.112	.183	.053	-.065	-.093
Und Social Studies	-.083	-.309	-.075	-.130	-.129	-.134
Und Biological Science	.009	.043	-.042	.029	.-93	.136
Und Physical Science	-.020	.501	-.038	.094	.141	.128
Graduate Humanities	.113	-.040	.150	.069	-.021	-.061
Graduate Social Science	-.060	-.349	-.046	-.140	-.176	-.148
Graduate Biological Science	.012	.078	.028	.059	.113	.142
Graduate Physical Science	-.040	.470	.050	.066	.147	.110
G Other Humanities	.088	-.008	.087	.056	.005	-.018
G Language	.101	-.057	.171	.055	-.002	-.046
G Arts	.012	-.036	-.013	-.012	-.065	-.067
G Basic Social Sciences	.102	-.038	.109	.099	.071	.047
G Social Science Professions	-.034	-.050	-.072	-.066	-.037	-.019
G Applied Social Science	-.149	-.323	-.107	-.211	-.192	-.224
G Basic Biological Science	.075	.135	.056	-.086	.128	.073
G Health	-.021	.103	-.050	.017	.033	.107
G Applied Biological Science	-.055	-.033	-.070	-.027	.011	.033
G Math/Physics	.001	.311	.006	.077	.062	.035
G Engineering	-.076	.297	-.046	.009	.082	.070
G Chemical/Earth Science	.019	.165	-.042	.028	.100	.077

Factors:
- I′ Reading Comprehension
- II′ Quantitative
- III′ Vocabulary
- IV′ Analytic
- V′ Data Interpretation and Technical Comprehension
- VI′ Easy Quantitative

Since these correlations of factor scores and nominal variables are point-biserial correlations, they are constrained by the marginal distributions of the variables. Thus the absolute values of the correlations are less informative than are the relative values. Within a factor, ranks of the correlations correspond to the order of means of the groups, but the absolute magnitudes of correlations depend on the difficulty of the factor and on the proportion of individuals in the group. For this reason, our discussion of construct validity will deal only with the rankings of the groups on the major factors.

Sex differences. As is commonly found, sex differences in favor of females appear on verbal Factors I′ and III′ (although the difference on the vocabulary Factor III′ is negligible, even taking into account the fact that the factor represents difficult items) and in favor of males on the quantitative Factor II′ and on the technical comprehension/data interpretation Factor V′. The analytic reasoning Factor IV′ shows a small sex difference in favor of females, in keeping with its strong relationship to reading comprehension, and this suggests that, although related to quantitative ability, this factor is not subject to the extreme differential selection and training emphasis that characterize quantitative ability.

English as a native language. This variable relates positively to all factors except quantitative ability, which suggests that native speakers enjoy an advantage over those examinees whose native language is not English.

Ethnic differences. The values of these correlations are not reported.[4] Ranks of the ethnic groups contrasted remain constant across all six factors. In the discussion of the factor pattern corresponding to partial correlations rather than to the present zero-order correlations, it will be noted that ranks of loadings vary considerably across factors.

Degree objective. All factors show a substantial positive relationship to the intention of going on to the doctorate, which suggests that students' career plans take abilities, related to those measured by this test, into account.

Recognition. The patterns of relationships of the factors to honors and awards for extracurricular achievements give considerable support to the construct validity of the factors. Preprofessional achievements were positively related to all six factors. Student government achievements were weakly but positively related to all factors except the difficult vocabulary factor. Literary and artistic achievements showed positive relationships to the verbal and analytic factors, but negative relationships to quantitative and technical factors. Community service, which may reflect responsibilities or ties to other than academic pursuits, lamentably showed negative relationships to all factors. So few candidates reported receiving a letter in athletics that correlations with this variable were not interpreted.

Major fields. The global classification of undergraduate major and intended graduate major field offers some evidence of construct validity. Self-selection and training would be expected to lend to some degree of sorting out by abilities of entrants into these general areas. Table 22 gives the ranks of each of the four groups on the four major factors. Ranks on Factors V′ and VI′ are similar to those on Factor II′. As would be expected, undergraduate and graduate majors in Humanities (including English) rank highest on reading comprehension and vocabulary, and Physical Science majors highest on quantitative ability. Social Science undergraduates (including Education) majors rank lowest on all four factors. The only changes in ranks that reflect the further selection accompanying the transition from undergraduate to intended graduate major are in vocabulary and analytic ability. Those who intend to go on to graduate work in Physical Sciences rank lowest on the vocabulary factor, dropping from a second ranking for undergraduate Physical Science majors, and moving Social Science and Biological Science graduate candidates each up one rank. Humanities and Physical Science graduate candidates rank first and second in Analytic Ability, a reversal of the ranks of undergraduate majors in these two areas.

Plotting the ranks of the four graduate groups, we obtain the profiles of Figure 5. These profiles illustrate the relatively even distribution of ranks among the Biological Science candidates, the low quantitative but high verbal and analytic ranks of those planning Humanities majors, and the low verbal but high quantitative and analytic ranks of those planning graduate study in the Physical Sciences. These global profiles demonstrate that the analytic factor is not identical with reading comprehension nor with quantitative ability, but do not rule out the possibility that analytic ability is simply a combination of V and Q.

For evidence on this issue, we turn to the more detailed groupings of Table 23. Table 23 gives the ranks on Factors I′ through IV′ of intended graduate majors in each of the 12 subgroupings of intended major field.

Examination of these more detailed categories reveals considerable variation within general areas.

Within the Social Sciences category, Basic Social Science majors show a markedly different profile from Professional or Applied groups. Figure 6 shows these profiles.

Within the Humanities, Language specialists rank higher than other Humanities majors on verbal factors, just below them on the analytical factor, and far below the second group on quantitative ability. Music and Art majors rank below both groups, but exceed Language majors on Quantitative ability. Figure 7 gives these profiles.

Comparing Figures 6 and 7, we see that the Language group's profile is quite similar to that of the Basic Social Science group except for a considerably lower analytic factor rank for the former. Although certain

Table 22

Ranks of Mean Scores
on Selected Geoplane Factors for Major Areas

Major Area	Percentage of Total		Factor I′ Reading Comprehension		Factor II′ Quantitative		Factor III′ Vocabulary		Factor IV′ Analytic	
	Under Graduate	Graduate	Under Graduate	Graduate	Under Graduate	Graduate	Under Graduate	Graduate	Under Graduate	Graduate
Humanities	16.5	13.6	1	1	3	3	1	1	2	1
Biological Science	21.5	21.4	2	2	2	2	2	3	3	3
Physical Science	14.9	12.7	3	3	1	1	3	2	1	2
Social Science	47.1	52.4	4	4	4	4	4	4	4	4

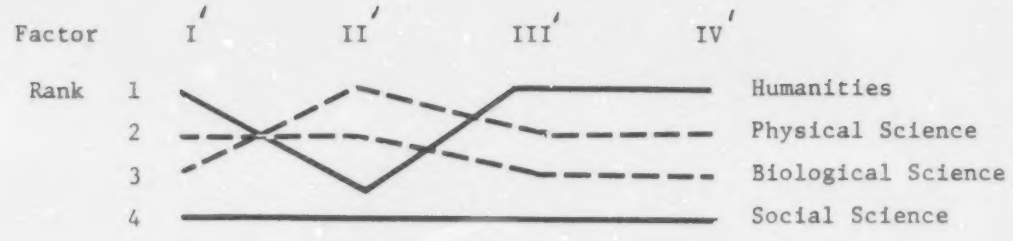


Figure 5. Ranks of Mean Scores on Selected Geoplane Factors for Major Graduate Groups

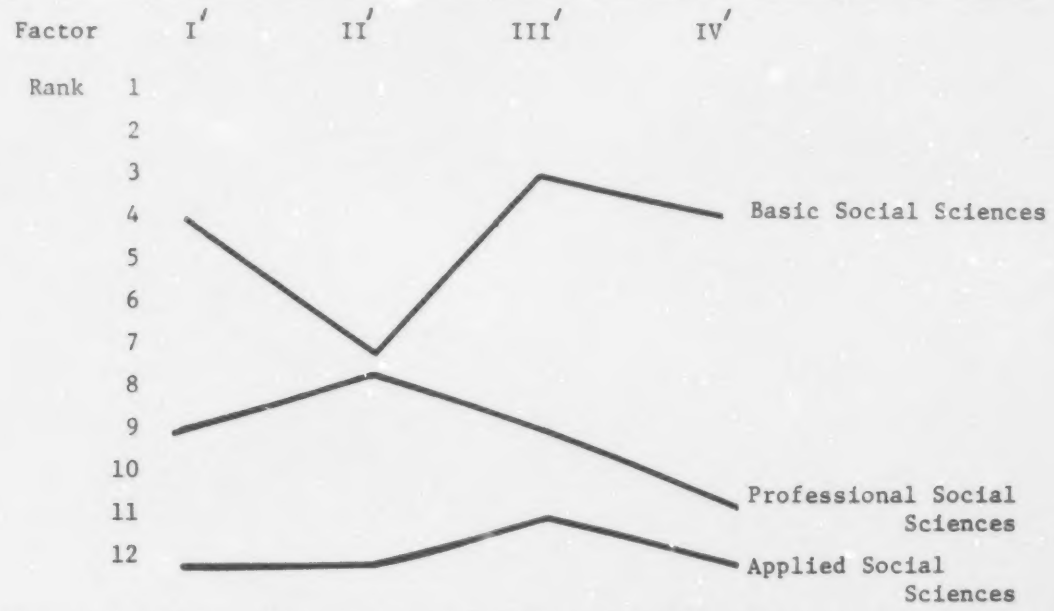


Figure 6. Ranks of Mean Scores on Selected Geoplane Factors for Social Science Graduate Subgroups

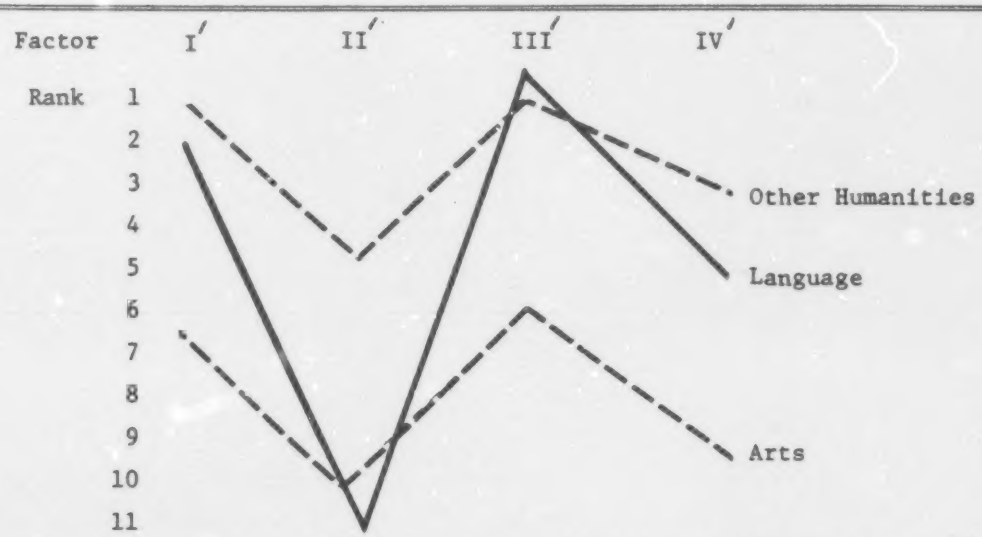


Figure 7. Ranks of Mean Scores on Selected Geoplane Factors for Humanities Graduate Subgroups

Table 23

Ranks of Mean Scores on Geoplane Factors
for Graduate Major Field Subgroups

Major Field Subgroups	Percentage	Factor I′ Reading Comprehension	Factor II′ Quantitative	Factor III′ Vocabulary	Factor IV′ Analytic
Other Humanities	3.4	3	6	3	4
Language	5.8	2	11	1	5
Arts	3.0	6	8	6	8
Social Science Profession	11.7	9	10	11	11
Basic Social Science	19.0	1	9	2	1
Applied Social Science	23.0	12	12	12	12
Applied Biological Science	2.5	10	7	10	10
Health	11.1	8	5	9	7
Basic Biological Science	7.9	4	4	4	2
Math/Physics	3.8	7	1	5	3
Engineering	5.2	11	2	8	9
Chem/Earth Science	3.6	5	3	7	6

majors, such as economics, may fit the high quantitative profile characteristic of science majors, it appears that the Psychology majors who dominate this category have a high verbal and analytic pattern more characteristic of Humanities profiles.

In the Physical and Biological Sciences, the analytic factor generally gives the strongest discrimination among subgroups. Figure 8 contrasts Basic Biological Sciences with Health, Agriculture, Home Economics, and Nutrition. Figure 9 contrasts Mathematics/Physics with Chemistry/Earth Sciences and with Engineering. In each case, persons entering the more theoretically oriented field show generally higher ranks, but the greatest rank differences, except for Basic Biological Sciences vs. Health on Factor III′ and Chemistry vs. Engineering on Factor I′, are on the analytic factor.

In these figures, the "hump" in quantitative ability usually associated with technical fields is conspicuously absent for Basic Biological Sciences, and the profile similarity between the Health subgroup and the Chemistry/Earth Sciences group is also of interest.

Over all groups the similarity of ranks on Factors I′ and III′ offers little evidence for discriminant validity of the reading comprehension and vocabulary factors, which suggests that they measure different aspects of a single ability. However, the evidence for the utility of the quantitative factor in discriminating Humanities and Social Science from Biological and Physical Science groups is striking.

There is also evidence that the analytic factor gives some information over and above the average level of V and Q, that is useful in discriminating a characteristic associated with the decision to enter more basic as opposed to more applied fields within the broader disciplines. The degree to which this characteristic is associated with success in graduate study in these fields cannot be determined from these data, but these results do confirm that V, Q, and A, by showing differing patterns of external relationships, are in fact measuring somewhat different characteristics. Such evidence of discriminant construct validity does not appear in these data for reading comprehension and vocabulary.

Primary factor loadings. In interpreting patterns of factor loadings, it must be kept in mind that we are discussing only covariation not explained by other factors. Thus a low factor loading does not imply a low correlation with a variable, but only that this factor shows low partial correlation with the variable. To demonstrate a high loading, a variable must be a relatively pure measure of a factor. Figure 10 shows two variables with identical correlations on Factor I′, but with very different loadings on this factor because of differing correlations with Factor II′. Although the correlation of variable 2 with Factor I′ is large, the Factor I′ loading of that component of variable 2 which is orthogonal to Factor II′ is small. Loadings thus tell the degree to which the actual correlation of a variable with a factor's residual

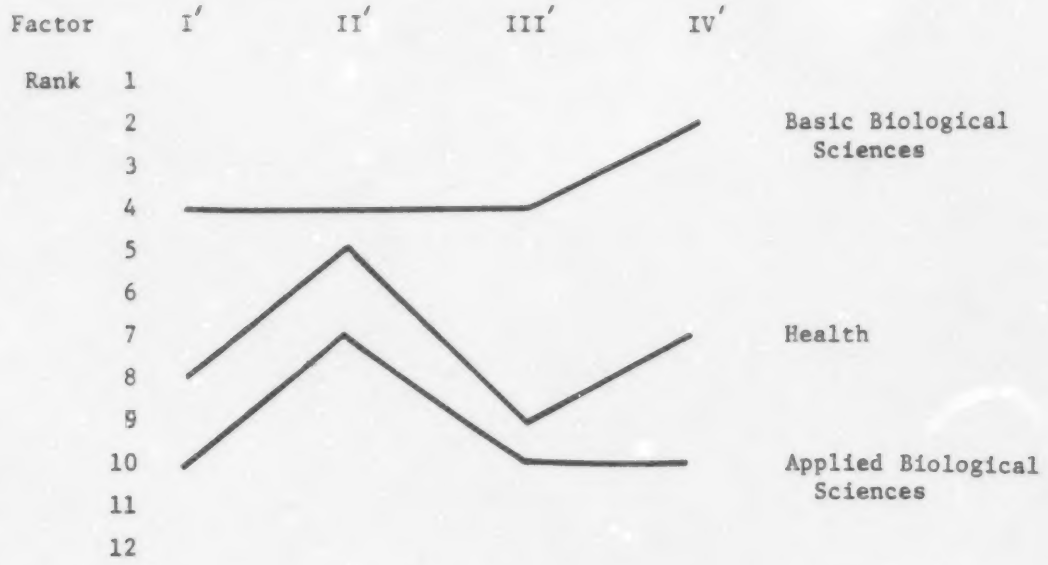


Figure 8. Ranks of Mean Scores on Selected Geoplane Factors for Biological Science Subgroups

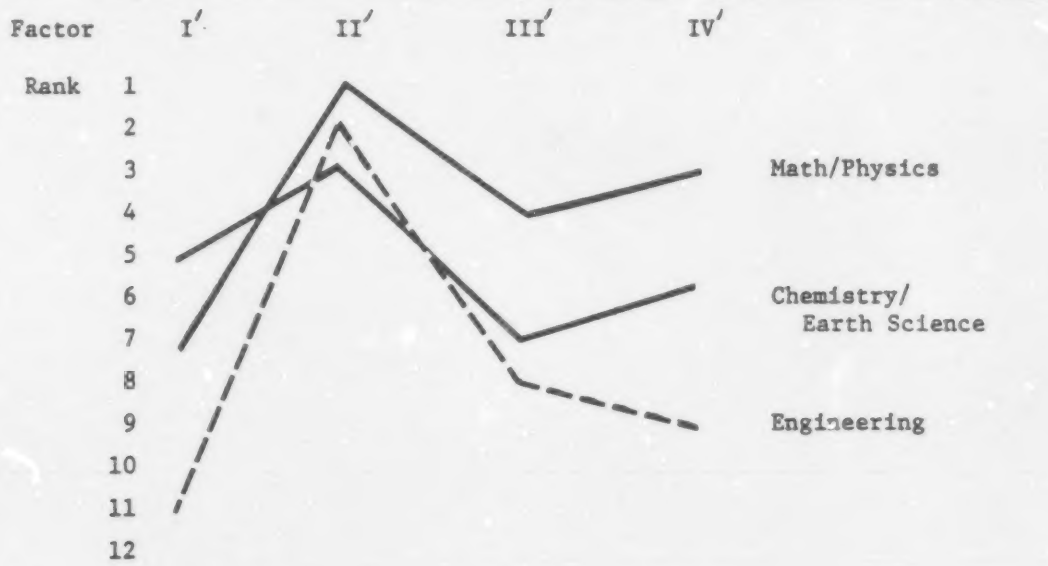
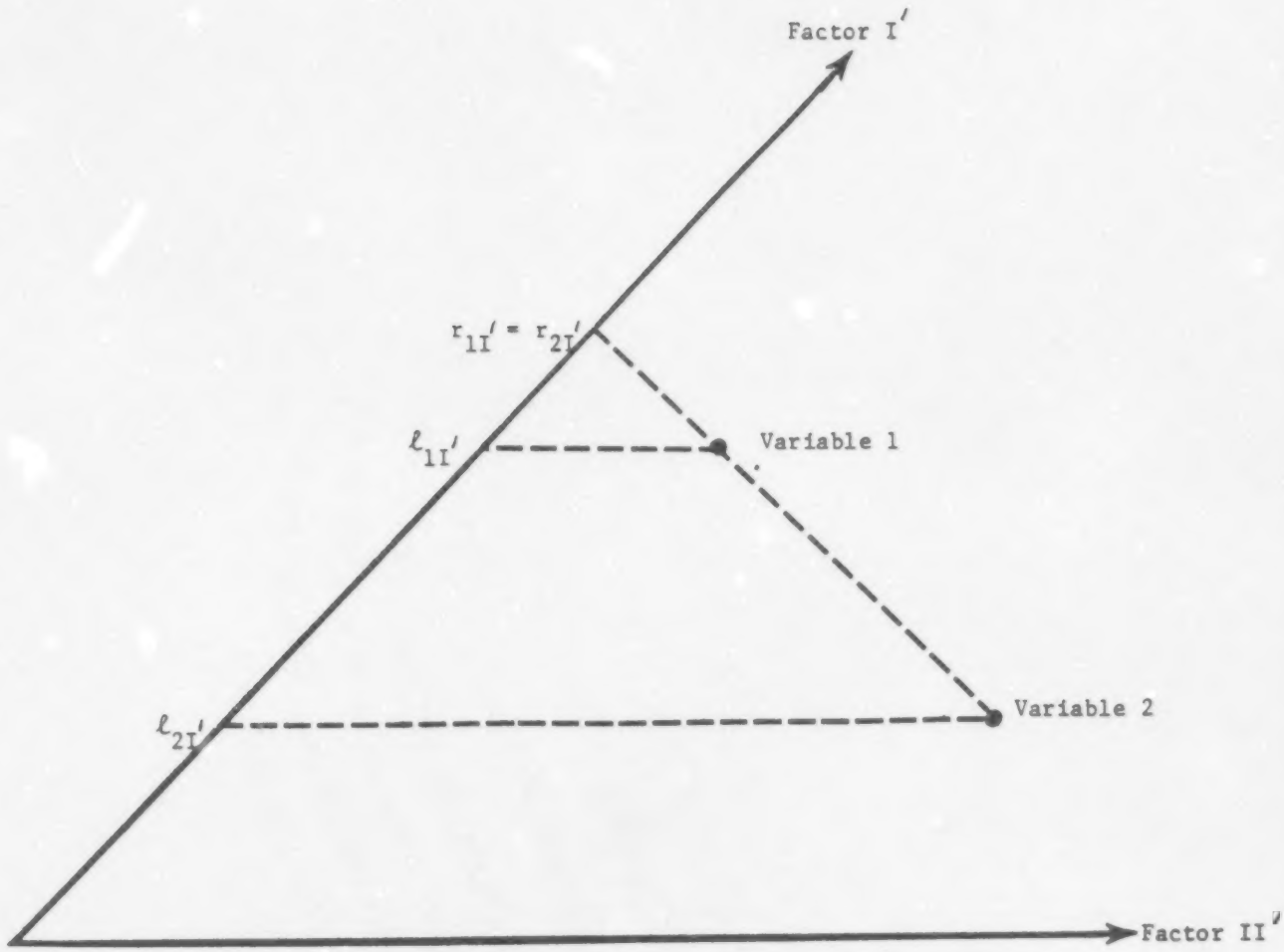


Figure 9. Ranks of Mean Scores on Selected Geoplane Factors for Physical Science Subgroups



r_{xy}: Correlation of Variable x with Factor y

ℓ_{xy}: Pattern Coefficient of Variable x with Factor y

Figure 10. Equal structural correlations and unequal pattern loadings with correlated factors

portion exceeds that anticipated from its correlation with other factors. However, if a factor were removed from the solution, loadings on all other factors could change markedly.

Factor loadings, analogous to partial correlations, are of utility in testing interpretations of factors, but are less related than are structure correlations to the relationships to be expected from operational subscores. For this reason, the primary extension loadings are reproduced (Table 24) for completeness, but no attempt is made to interpret them in detail. Instead, some discussion of a few illustrative patterns, which may raise interesting hypotheses for further study, is offered.

Grades in major fields. All factors continue to show positive loadings on grades in major fields, with the analytic and vocabulary loadings being reduced the least by the removal of variance shared with other factors.

Sex differences. The pattern of loadings is similar to that of correlations previously discussed, with a female advantage on verbal and analytic factors and a male advantage on quantitative factors. The only change appears in Factor V′, a data interpretation and technical passage factor that combines verbal, quantitative, and analytic skills. When the sex differences explained by other factors are partialled out, the residual shows a sex difference in favor of females.

English as a native language. The relationship to the reading comprehension factor is even stronger for factor loadings than for zero-order correlations. All other loadings are less than their corresponding correlations, with vocabulary and quantitative loadings becoming negative, which indicates that the deficit in these factors as a result of working in a second language is less than that predicted by reading comprehension differences. Native speakers continue to have an advantage on the analytic and data interpretation factors beyond that predicted by reading comprehension. This latter finding is consistent with recent experimental evidence (D′Angelgan & Tucker, Note 2).

Ethnic differences. The ranking of ethnic groups on reading comprehension loadings is the same as that on correlations. However, the ethnic variance of the residual portions of Factors II′ through V′ decreases markedly when reading comprehension differences are taken into account, and rankings of loadings on these factors change from those observed with the correlations. In particular, blacks move above the mean on that component of analytic ability not related to other factors, and whites move below the mean on the independent components of vocabulary and quantitative of analytic ability. Ethnic differences on Factors II′ through IV′ thus appear smaller than those on reading comprehension. This is partly an artifact of differences in difficulty among the factors, but warrants further exploration with actual subscores. The result suggests that ethnic variance on the total analytic score may be smaller than is the case with the verbal and quantitative scores.

Table 24

Geoplane Extension Primary Loadings
(partial correlations)

Background Variable	Factor I′	II′	III′	IV′	V′	VI′
Sex	-.095	.456	-.008	-.268	-.021	.178
English	.476	-.226	-.135	.110	.033	-.073
Major Grade	.041	.038	.112	.190	.064	.023
All Grade	.048	.037	.105	.187	.027	.046
Degree Objective	.026	.168	.156	.064	-.055	.029
Student Government	-.030	-.003	-.017	.030	.017	.044
Preprofessional Achievement	-.002	.028	.050	-.029	.030	.254
Community Service	.050	-.004	.002	-.028	.097	-.078
Literary	.070	-.025	.121	.017	-.089	-.073
Artistic	.143	.003	-.030	-.009	-.056	-.056
Und Humanities	.128	-.194	.212	.076	-.141	-.062
Und Social Studies	.041	-.337	.013	.032	.007	-.040
Und Biological Science	-.065	-.024	-.044	-.010	.131	.142
Und Physical Science	-.116	.703	-.189	-.112	-.014	-.043
Graduate Humanities	.101	-.103	.144	-.068	-.097	-.062
Graduate Social Science	.103	-.376	.057	.014	-.065	-.039
Graduate Biological Science	-.106	.001	-.035	.030	.141	.136
Graduate Physical Science	-.128	.669	-.191	-.127	.023	-.046
G Other Humanities	.086	-.053	.064	.035	.048	-.030
G Language	.049	-.149	.201	.056	-.057	-.015
G Arts	.079	-.004	-.041	.053	-.089	-.096
G Basic Social Sciences	.014	-.167	.131	.111	-.017	.065
G Social Science Professions	.049	-.019	-.061	-.080	-.002	-.040
G Applied Social Science	.059	-.252	-.013	-.039	-.050	-.127
G Basic Biological Science	-.017	.089	-.005	.004	.087	.027
G Health	-.087	-.050	-.020	.028	.072	.127
G Applied Biological Science	-.075	-.049	-.043	.013	.075	.055
G Math/Physics	-.054	.447	-.950	-.033	-.061	-.084
G Engineering	-.156	.439	-.971	-.095	.026	-.005
G Chemical/Earth Science	.013	.210	-.127	-.080	.072	.011

Factors:
I′ Reading Comprehension
II′ Quantitative
III′ Vocabulary
IV′ Analytic
V′ Data Interpretation and Technical Comprehension
VI′ Easy Quantitative

Global major field. Patterns of loadings are markedly different from correlations with major field. Because of the extremely high level of Physical Science majors on the quantitative factor, the rank of their loadings on all other factors drops to fourth. Similarly, because of the extremely low level of Social Science majors on the quantitative factor, the rank of their loadings on all other factors goes up. That is, considering their overall ability, Social Science majors appear relatively stronger on verbal and analytic skills than on quantitative skills. This was not clear from the raw correlations in which Social Science majors ranked at the bottom on all factors, although this pattern did appear in the correlations of the Basic Social Science subgroup.

The factor pattern resulting from the geoplane extension thus appears not only to generally confirm the interpretation given to the geoplane extension structure correlations but also to add more detail at the expense of more complex interpretive demands. The hypotheses raised concerning underlying sources of group differences cannot be tested in this exploratory study, but may warrant further examination.

Extension of Varimax Factors

As was shown earlier, the varimax description of the item-parcel variance of the GRE Aptitude Test bears a certain resemblance to the geoplane structure, in spite of the constraint of orthogonality on the factors. In both solutions, reading comprehension, discrete verbal, and quantitative item parcels loaded on distinct factors, and data interpretation and a technical reading passage determined one or more additional factors. The major difference was in the allocation of analytic item parcel variance: in the geoplane solution, to a major factor strongly correlated with the reading comprehension factor, and in the varimax solution (in which correlated factors are precluded), principally to the factor tapping reading comprehension, making it a general verbal reasoning factor, and additionally to a minor factor representing a component of the analytic clusters unrelated to the general verbal reasoning factor. In addition, the geoplane solution, by combining data interpretation and technical reading on a single factor, has made room for a doublet factor representing very easy quantitative items.

In discussing the extension of the varimax solution into background variables, we will again focus our attention on four factors, including the analytic Factor VI′ along with the major Factors I, II, and III, but bearing in mind that the varimax analytic factor is not comparable to the geoplane analytic factor.

Indeed, because the varimax analytic factor is orthogonal to the major dimension of verbal reasoning, we might expect its correlations with background variables to behave less like the correlations of the geoplane Factor IV′ structure than like the partial correlations of the geoplane primary extension loadings.

Table 25 gives the varimax extension correlations, which because of orthogonality are identical to primary extension loadings for these factors.

All factors show positive correlations with grades and degree objective, with large correlations arising from the verbal reasoning and vocabulary factors, followed by the correlations of quantitative ability and the analytic factor.

Sex differences. Again, the verbal (I & III) and analytic (I & VI) factors show sex differences in favor of females, and the quantitative factor (II) shows a large difference in favor of males. Interestingly, the science passage and data interpretation factors, which are separate in this solution, show that the slight advantage for males in these technical areas is the result of the data interpretation rather than of the technical (biology) passage.

Ethnic differences. Ethnic rankings vary on these orthogonal factors, with whites ranking highest on Factor I', blacks highest on Factor VI, and others (including Orientals) first on Factors II and III. Hispanics ranked second on Factors I and VI. This variation is more comparable to that obtained with geoplane loadings than with the general factor-saturated geoplane correlations.

English as a native language. Again, as in the geoplane solution, all but the quantitative varimax factor show positive correlations with this variable.

Extracurricular achievements. Student government participation shows positive loadings on the verbal reasoning, quantitative, and analytic factors, but a negative relationship to the orthogonal discrete verbal factor. Preprofessional achievements correlate positively with Factors I, II, and III, but show a slight negative loading on the analytic Factor VI. Community service again tends to show negative correlations with these measured abilities, but manages to be at least non-negatively related to vocabulary. Literary and artistic achievements show similar patterns on Factors I, II, and III, negatively related only to the quantitative factor and essentially showing no relationship to the varimax analytic factor.

The relationship of the science passage Factor IV to extracurricular achievements raises some question concerning the construct validity of this particular component of science passage variance. Negative correlations with all but artistic achievements, coupled with the lowest correlation of any factor with grades, suggest that the portion of variance of these item clusters that remains when variance resulting from major factors has been removed may measure little beyond passage-specific variance. Factor V, data interpretation, on the other hand, correlates particularly with preprofessional achievements, and shows some relationship to grades, which suggests that this independent component of data interpretation contributes additional valid information to the instrument.

Table 25

Varimax Extension Loadings

Background Variable	Factor I	II	III	IV	V	VI
Sex	-.123	.380	-.027	.001	.081	-.107
English	.394	-.141	.051	.055	.093	.017
Major Grade	.217	.156	.170	.042	.065	.127
All Grade	.226	.155	.154	.010	.056	.108
Degree Objective	.120	.197	.106	.006	.013	.063
Student Government	.018	.028	-.029	-.013	.017	-.010
Preprofessional Achievement	.015	.039	.053	-.007	.052	-.018
Community Service	-.026	-.090	.007	-.024	-.055	.003
Literary	.034	-.053	.134	-.005	-.046	-.004
Artistic	.006	-.022	.024	.032	-.049	-.060
Und Humanities	.106	-.168	.200	-.002	-.111	.004
Und Social Studies	-.003	-.305	-.030	-.031	-.018	-.046
Und Biological Science	.020	.075	-.073	.044	.061	.000
Und Physical Science	-.128	.516	-.082	-.006	.071	.061
Graduate Humanities	.091	-.089	.155	.006	-.077	.020
Graduate Social Science	.021	-.347	.007	-.032	-.068	-.077
Graduate Biological Science	.019	.103	-.065	.027	.079	.030
Graduate Physical Science	-.149	.487	.090	.010	.084	.058
G Other Humanities	.074	-.040	.083	.061	-.042	.015
G Language	.075	-.101	.177	.000	-.043	.002
G Arts	.027	-.052	-.003	-.006	-.069	.025
G Basic Social Sciences	.112	-.055	.096	.015	-.041	.023
G Social Science Professions	-.007	-.027	-.062	-.018	.022	-.069
G Applied Social Science	-.085	-.319	-.035	-.038	-.052	-.061
G Basic Biological Science	.026	.121	.021	.070	.047	.043
G Health	.014	.036	-.068	-.013	.037	.002
G Applied Biological Science	-.023	-.011	-.071	-.024	.053	.001
G Math/Physics	-.074	.306	-.016	-.009	.003	.061
G Engineering	-.144	.321	-.062	-.023	.075	.026
G Chemical/Earth Science	-.019	.172	-.069	.053	.058	.010

Factors:
I Verbal Reasoning
II Quantitative
III Vocabulary
IV Technical Reading Comprehension
V Data Interpretation
VI Analytic

Global major field. Table 26 shows the rankings on varimax factors of the undergraduate and intended graduate majors in the four global field categories.

The major differences between these ranks and those obtained from the correlations with oblique factors are in the relative improvement of Social Science majors on the more purely verbal Factors I and III, the oblique counterparts of which had some correlation with quantitative ability, and the reversal in the ordering of Humanities, Biological Sciences, and Physical Sciences on the analytic factor, which no longer has the strong verbal component of its oblique namesake. For Factors I, II, and III, ranks resulting from the restriction to orthogonal factors are similar to those found in the factor pattern of the oblique solution. The first rank of Physical Science undergraduate majors on the orthogonal analytic factor, however, is consistent with the correlation rather than the loading of this group on the more verbal geoplane analytical factor. The drop in rank of graduate Humanities majors on this factor as compared with their rank of first on oblique Factor IV′ further reflects the effect of removing the verbal component from analytic item variance, and confirms the interpretation of the orthogonal analytic factor as measuring a different dimension than that of the oblique analytic factor.

Major field subgroups. Table 27 gives the rankings of intended graduate major subgroups on varimax Factors I - III and VI, and marks major changes from geoplane structure ranks.

Examination of the changes in group profiles reveals that making the verbal reasoning factor orthogonal to quantitative ability has increased the ranks of Music/Art, Professional, and Health groups at the expense of more quantitatively oriented groups. In particular, the extremely low ranks of the Mathematics/Physics and Chemistry/Earth Sciences groups do not reflect their actual relatively high GRE V scores. The rank of professional groups also improves on Factors II and III, however, as does the rank of the Applied Social Science group on that component of discrete verbal items orthogonal to verbal reasoning. This change also does not reflect the actual standing of Education majors on GRE V. The major reshuffling of ranks occurs with the analytic factor. The most verbally oriented groups, Language and Basic Social Sciences, rank far lower on the orthogonal component of analytic ability than they did on the oblique analytic factor. The less verbal groups, Engineering, Music/Art, and Math/Physics, enjoy noticeable improvement in their ranks.

These changes in rankings of major field subgroupings that result from constraining the factors to orthogonality help to clarify the contributions of independent ability components to the construct validity of the instrument. However, the abilities measured by the Aptitude Test are not, in fact, independent, and this is reflected in the changed patterns of correlations of background variables with the varimax factors.

Table 26

Ranks of Mean Scores on Selected Varimax Factors
for Major Areas

Major Group	Factor I Verbal Reasoning		II Quantitative		III Vocabulary		VI Analytic	
	U	G	U	G	U	G	U	G
Humanities	1	1	3	3	1	1	2	3
Biological Sciences	2	3	2	2	3	2	3	2
Social Sciences	3	2	4	4	2	3	4	4
Physical Sciences	4	4	1	1	4	4	1	1

Table 27

Ranks of Mean Scores on Varimax Factors
for Major Field Subgroups

Major Subgroup Field	Factor I Verbal Reasoning	II Quantitative	III Vocabulary	VI Analytic
Other Humanities	3	8-	3	6-
Language	2	11	1	9--
Arts	4+	9	5	4++
Social Science Professional	7+	7++	8++	12
Basic Social Science	1	10	2	5--
Applied Social Science	11	12	7+++	11
Applied Biological Science	9	6	12-	10
Health	6+	5	10	8
Basic Biological Science	5	4	4	2
Math/Physics	10--	2	6	1+
Engineering	12	1	9	3+++
Chem/Earth Science	8--	3	11--	7

Rank changes +++ increase 5
++ increase 3
+ increase 2

-- decrease 3
- decrease 2

In general, these changes appear to be in the direction of lower construct validity for the orthogonal components than for the more directly subscore-related oblique factors. In particular, the relationship of analytical ability to more theoretical orientation within global field is less clear with the varimax analytic factor than with the oblique analytic factor, and verbal abilities of more quantitatively oriented groups appear to be seriously underestimated by orthogonal factors.

The patterns of correlations of the oblique factors, on the other hand, are more consistent with patterns of abilities ordinarily associated with self-selection into these fields, and, when combined with the reported relationships to background variables, grades, and extracurricular achievements, they yield supportive evidence for the construct validity of the verbal, quantitative, and analytic factors isolated in the geoplane analysis.

Discussion and Summary

Structure of the New Test

The factor structure of the verbal and quantitative sections of the restructured test has been little affected by the changes made in order to introduce the analytical module, i.e., the introduction of shorter reading passages and quantitative comparison items. The major verbal and quantitative factors in the restructured test were defined, as they were in the test prior to restructuring, by (a) reading comprehension items, including easy sentence completion items, (b) discrete verbal items (vocabulary), especially the more difficult antonym and analogy items, and (c) regular quantitative items. Some separation of quantitative items into easy and difficult quantitative factors was apparent in the restructured test, with quantitative comparison items and easier regular mathematics items being associated with the easy quantitative factor.

Even with the additional analytical items in the restructured test, the verbal and quantitative factors in the test before and after restructuring remain similar, accounting for comparable portions of each test's common variance.

The addition to the GRE Aptitude Test of the new analytical items has introduced new components of variance related to the analysis of explanations item type, especially those having certain keyed choices, and to a lesser extent, logical diagram items, which appear complex, loading on the reading comprehension and quantitative factors. An additional minor factor associated with analytical reasoning items also emerged in one analysis, but this may also have reflected the slight speededness of this section, since these items appeared in the final position of the section.

The major oblique factors in the restructured test were found to be reading comprehension, vocabulary, quantitative ability, and analytical reasoning. The latter factor was highly correlated with reading comprehension.

Difficulty and Speededness

The reading comprehension and vocabulary factors showed a much clearer relationship to item difficulty than was apparent in a previous factor analysis, with the vocabulary factor having its highest loadings from difficult items. The degree to which these factors represent different abilities, rather than nonlinear functions of a single ability, is uncertain and can be determined only by their relation to external variables.

Rearrangement of items in the verbal section of the restructured test by placing difficult discrete items, instead of reading comprehension items, at the end of the section had the positive effect of reducing the dependence of verbal scores on the ability to work rapidly. Although, according to traditional measures of test speededness (i.e., percentage attempting the final item and the item number reached by 75% of examinees), the verbal section still appears somewhat speeded, no verbal speed factors emerged from our analyses as they had in the factor analysis of the test prior to restructuring. Thus examinees who do not reach the final items on the restructured test are less likely to have answered them correctly if they had reached them, thereby reducing the dependence of scores on speed.

There was, however, a minor factor defined as analytical speed. Thus, as it now stands, variance in the performance of examinees on the analytical section of the test is somewhat dependent on their ability to work quickly on the two analytical item types (analysis of explanations and analytical reasoning) at the end of each separately-timed analytical section. As with the test prior to restructuring, there was no separate factor associated with speed in the quantitative domain.

Complexity of Analytical Items

Analyses suggested that the analysis of explanations item type is quite complex. The multidimensionality of this item type was seen from distinct dimensions associated with keyed item choices. Upon inspection of this item type, one might suspect that the item would tap different skills depending on its correct answer. This suspicion was confirmed empirically. Choice C items (deducible from) and especially Choice B (possible adequate explanation) and Choice D (relevant to) items were relatively better indicators of analytical ability than were Choice A (inconsistent with) and E (irrelevant to) items, which were generally easier and more closely associated with reading comprehension ability.

The practical usefulness of this finding for test development is uncertain apart from its implications for using this keyed-choice dimension for developing items and for balancing alternate forms. Other considerations, such as those related to guessing, would probably dictate the inadvisability of including more items keyed as B, C, D. It might be possible, however, to score A- and E-choice items with the verbal items with which they are more closely related.

Although the relevance of a keyed choice dimension in the analysis of explanations items was suggested, the current tentative classification of analytical items according to whether they use logically related rules, spatial relationships, or rules that are not logically related was not confirmed empirically. This is not to suggest, however, that this classification does not have some face validity. With respect to this item type, there was some suggestion in the data that the distinction between ordered (e.g., distances and calendar dates) and unordered relationships may be an important distinction.

The logical reasoning item subtype of analytical reasoning items did not seem to add anything to the restructured test in terms of variance associated with analytical reasoning. These items were found to be highly related to reading comprehension ability.

The analysis of explanations item type appeared to be not only complex, but sensitive to stimulus material. For example, the items associated with one analysis of explanations passage, which contained statistical information about hospital admissions, etc., was more related to data interpretation items than to analytical ability.

Relationships to Background Variables

The extension of the orthogonal and oblique item cluster factors into demographic variables, grades, extracurricular achievement, and major fields that were derived from the background questions yielded evidence that supported the discriminant construct validity of the verbal, quantitative, and analytic factors of the test. No evidence that supported differential construct validity of the reading comprehension and vocabulary factors was obtained in the preferred oblique extension analysis, although orthogonal verbal reasoning and vocabulary factors did give different patterns of relationships to background variables in the varimax extension analysis.

Issues Raised

In general, the conclusions that were drawn in the present study have been supported by using alternative methods (e.g., various rotational schemes and subscore as well as item-level analyses) and by replicating results using alternate forms. The more stable item-parcel results closely parallel those obtained from item-level analyses. The degree to which difficulty-related factors that arise from both techniques stem from violations of assumptions resulting from the impact of guessing requires further analysis.

Hypotheses concerning possible differences in sensitivity of factors to sex and ethnic differences were raised. Since the factors differed in difficulty, these hypotheses can best be investigated with actual subscores, rather than with the derived factors employed in the present analyses. Therefore, no firm conclusions were drawn with respect to these hypotheses.

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Footnotes

[1]Names of specific item types are underlined in this report. Generic item descriptions are not underlined.

[2]In the analysis of explanations item type, answer choices are the same for every item. After reading about a situation, and a result, the examinee is confronted with a statement. The statement is judged in order to be: (A) inconsistent with, or contradictory to something in the situation, the result, or both; or, if not, (B) presenting a possible adequate explanation of the result; or, if not, (C) deducible from the situation or result; or, if not (D) relevant to an explanation of the result; or if not, (E) irrelevant to an explanation of the result. A situation is followed by several results, each result constituting a new item, but a decision among the same five choices must be made for each item. The set of possible adequate explanations is not made explicit.

[3]As Carroll (1945) pointed out in the context of the analysis of the Seashore Pitch Discrimination test, spurious difficulty factors can also arise in the analysis of tetrachoric or item cluster correlations of multiple-choice items when guessing is extensive.

[4]Since with these data only ranks of groups are interpretable, it was felt that no useful purpose would be served by reporting magnitudes of these correlations, which could be taken out of context and overinterpreted.

Appendix

Examples of Analytical Item Types

ANALYSIS OF EXPLANATIONS

Directions: For each set of questions, a fact situation and a result are presented. Several numbered statements follow the result. Each statement is to be evaluated in relation to the fact situation and result.

Consider each statement separately from the other statements. For each one, examine the following sequence of decisions, in the order A, B, C, D, E. Each decision results in selecting or eliminating a choice. The first choice that cannot be eliminated is the correct answer.

A Is the statement inconsistent with, or contradictory to, something in the fact situation, the result, or both together?
If so, choose A.
If not,

B Does the statement present a possible adequate explanation of the result?
If so, choose B.
If not,

C Does the statement have to be true if the fact situation and result are as stated?
If so, the statement is deducible from something in the fact situation, the result, or both together; choose C.
If not,

D Does the statement either support or weaken a possible explanation of the result?
If so, the statement is relevant to an explanation; choose D.

E If not, the statement is irrelevant to an explanation of the result; choose E.

Use common sense to decide whether explanations are adequate and whether statements are inconsistent or deducible. No formal system of logic is presupposed. Do not consider extremely unlikely or remote possibilities.

Sample Set

Situation: In an attempt to end the theft of books from Parkman University Library, Elnora Johnson, the chief librarian, initiated a stringent inspection program at the beginning of the fall term. At the library entrance, Johnson posted inspectors to check that each library book leaving the building had a checkout slip bearing the call number of the book, its due date, and the borrower's identification number. The library retained a carbon copy of this slip as its only record that the book had been checked out. Johnson ordered the inspectors to search for concealed library books in attaché cases, bookbags, and all other containers large enough to hold a book. Since no new personnel could be hired, all library personnel took turns serving as inspectors, though many complained of their embarrassment in conducting the searches.

Result: During that term Margaret Zimmer stole twenty-five library books.

15. **Zimmer stole the books before the inspection system began.**

The answer to this question of average difficulty is A because the statement is inconsistent with the information given in the situation and the result. According to the situation, the inspection system was initiated at the beginning of the fall term, and, according to the result, Zimmer stole the books during that term.

16. **Zimmer dropped the books out of a second-story window into a clump of bushes and retrieved them after she left the building.**

Since the statement could be true given the information in the situation and the result, this statement is consistent with the information given, so the correct answer is not A. The next option to be considered is B. The statement is a possible explanation of the result, since Zimmer could have avoided the inspection system in this way. This question is an easy one.

17. **During the term, if Zimmer carried a bookbag out of the library entrance door during regular hours, an inspector was supposed to check it.**

This statement is not inconsistent with the information given, so the correct answer cannot be A. Although the statement brings to mind two possible explanations of the result (that Zimmer removed the books after regular hours, or that a negligent inspector failed to check her bag), it does not actually state either of these possibilities. Therefore, the correct answer cannot be B. At this point, in fact, one might be tempted to conclude that the statement weakens a possible explanation of the result (an explanation stating that Zimmer stole the books by hiding them in her bookbag) and might therefore decide that D is the correct answer. However, according to the directions, the next option to be considered is C. The statement can be deduced from the information given since it is stated that inspectors had been ordered to search for concealed library books in bookbags. The correct answer to this question is therefore C.

18. **The library had at one time kept two carbon copies of each checkout slip.**

This statement is not inconsistent with the information given, is not a possible explanation of the result, cannot be deduced from the information given, and does not support or weaken a possible explanation of the result. Information about the system used in the past is not relevant to any explanation of the result, so the correct answer is E.

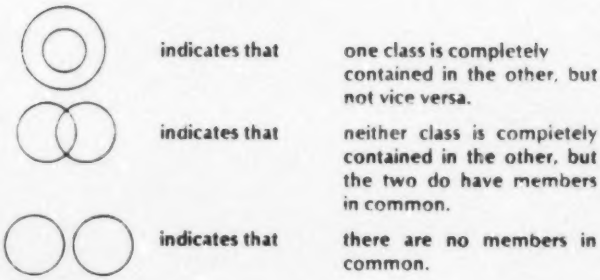
19. **The doors to the library fire escapes are equipped with alarm bells set off by opening the doors.**

This statement is not inconsistent with the information given, and it is not a possible explanation of the result. It cannot be deduced since it is not necessarily true given the information in the situation and the result. The correct answer is D because the statement weakens a possible explanation of the result. For instance, an explanation stating that Zimmer dropped the books from a fire escape to a confederate below would be unlikely if it were known that the fire escape doors could not be opened without setting off an alarm.

LOGICAL DIAGRAMS

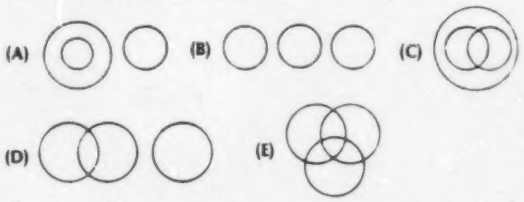
Directions: In this part, you are to choose from five diagrams the one that illustrates the relationship among three given classes better than any of the other diagrams offered.

There are three possible relationships between any two different classes:


indicates that
one class is completely contained in the other, but not vice versa.
indicates that
neither class is completely contained in the other, but the two do have members in common.
indicates that
there are no members in common.

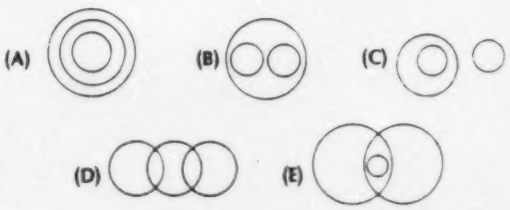
Note: The size of the circles does not indicate relative size of the classes.

Example: Birds, robins, trees



The correct answer, (A), shows that one of the classes (trees) has no members in common with the other two. (No trees are either birds or robins, and no birds or robins are trees.) (A) also shows that one of the two remaining classes (robins) is completely included in the other class (birds).

The five possible choices for the sample problems are given below.



20. **Nuts, pecans, forks**

One of the classes (pecans) is completely contained in another (nuts). That is, all pecans are nuts, but the category of nuts includes other kinds of nuts as well as pecans. The third class (forks) has no members in common with either of the other two classes. Therefore, the correct answer is (C).

21. **Adult women, infants, black-haired people**

Since two of the classes (adult women and infants) have no members in common, the correct answer must include two circles that do not overlap. Black-haired people may be adult women, and adult women may be black-haired people, but neither class is completely contained in the other. The same is true of the relationship between infants and black-haired people. The correct answer is therefore (D), which shows that, while two of the classes have no members in common, each of them has some members in common with the third class.

ANALYTICAL REASONING

Directions: Each question or group of questions is based on a passage or set of statements. In answering some of the questions it may be useful to draw a rough diagram. Choose the best answer for each question and blacken the corresponding space on your answer sheet.

Questions 22-23

(1) It is assumed that a half tone is the smallest possible interval between notes.
(2) Note T is a half tone higher than note V.
(3) Note V is a whole tone higher than note W.
(4) Note W is a half tone lower than note X.
(5) Note X is a whole tone lower than note T.
(6) Note Y is a whole tone lower than note W.

22. Which of the following represents the relative order of the notes from the lowest to the highest?

(A) X Y W V T (B) Y W X V T (C) W V T Y X
(D) Y W V T X (E) Y X W V T

The answer to this relatively easy question can be determined by reading the six given statements and understanding the relationships among them. The relationships may be clarified by drawing a simple illustrative diagram: T

V
X
W

Y

The diagram shows the relative order of the notes; since the question asks for the order from the lowest note to the highest, the correct answer is (B).

23. Which of the following statements about an additional note, Z, could NOT be true?

(A) Z is higher than T. (B) Z is lower than Y.
(C) Z is lower than W. (D) Z is between W and Y.
(E) Z is between W and X.

Since W and X are a half tone apart (statement 4), and since a half tone is assumed to be the smallest possible interval between notes (statement 1), Z cannot be between W and X. The correct answer is therefore (E). The question can also be answered by referring to the diagram.

Questions 24-25

(1) You cannot enter unless you have a red ticket.
(2) If you present a blue form signed by the director, you will receive a red ticket.
(3) The director will sign and give you a blue form if and only if you surrender your yellow pass to him.
(4) If you have a green slip, you can exchange it for a yellow pass, but you can do so only if you also have a blue form signed by the director.
(5) In order to get a red ticket, a person who does not have a driver's license must have a blue form signed by the director.
(6) You can get a yellow pass on request, but you can do so only if you have never had a green slip.

24. The above procedures fail to specify

(A) whether anything besides a red ticket is required for entrance
(B) whether you can exchange a green slip for a yellow pass
(C) the condition under which the director will sign the blue form
(D) how to get a red ticket if you have a yellow pass
(E) whether it is possible to obtain a red ticket if you do not have a driver's license

To answer this question, it is necessary to determine what information is NOT given. The information in options (B), (C), and (E) is given in statements 4, 3, and 5, respectively. The information in (D) is provided by statements 3 and 2 taken together. Statement 1, the only statement that specifically mentions a requirement for entrance, does not say that a red ticket is the only requirement for entrance. The correct answer therefore is (A).

25. Which of the following people can, under the rules given, eventually obtain a red ticket?

I. A person who has no driver's license and who has only a green slip
II. A person who has no driver's license and who has only a yellow pass
III. A person who has both a driver's license and a blue form signed by the director

(A) I only (B) II only (C) I and II only
(D) II and III only (E) I, II, and III

The answer to this moderately difficult question requires combining information from several of the given statements. The rules specify only one way of obtaining a red ticket—the presentation of a blue form signed by the director (statement 2). The person described in III, therefore, can obtain a red ticket by presenting the blue form. The person described in II can obtain the blue form by surrendering the yellow pass and then presenting the blue form to obtain a red ticket. The person described in I, however, as one who does not have a driver's license, must have a signed blue form in order to get a red ticket (statement 5). The director will sign the blue form and give it only to someone who surrenders a yellow pass (statement 3). Since this person has only a green slip, he can get a yellow pass neither on request (statement 6) nor by exchanging his green slip for a yellow pass (statement 4). Therefore, a person who has no driver's license and who has only a green slip cannot obtain a red ticket. The correct answer is (D), II and III only.